Appendix C. Assets at Risk and their Role in the Fire Plan

Introduction

The primary goal of fire protection in California is to safeguard the wide range of assets found across wildland areas. These assets include range,life and safety, timber, recreation, water and watershed, air quality, cultural and historic resources, unique scenic areas, life and safety, structures, wildlife, plants, and ecosystem health. This appendix to the fire plan describes these assets and discusses approaches to assessing their economic and non-commodity values. It also addresses how estimates of these asset values will be used in the fire plan process.

Knowledge of the types and magnitudes of assets at risk to wildfire, as well as their locations, is critical to fire protection planning. Given the limits on fire protection resources, these resources should be allocated, in part, based on the magnitude of the assets. At the margin, knowledge of assets at risk is also necessary to choose those prefire management projects which will provide the greatest benefit for a given amount of investment. For the department, the primary concern regarding prefire projects is the reduction of suppression costs; of secondary concern is reducing the fire risk faced by the various assets described here.

Thus, as a part of the overall fire plan process, assets will be addressed at two levels. First, generalized assets at risk will be estimated and summed across the state to indicate what areas contain highly valued assets. These assets will be overlain with a measure of likelihood of occurrence of a large damaging fire. These statewide assessments will be refined at the ranger unit level through a process that includes the participation of stakeholders in the various assets. Those areas with the highest combined asset values and fire risk will be targeted for prefire management projects, particularly where those projects would significantly reduce suppression costs should a fire start in the project area during high fire hazard weather. Second, as potential projects are identified in these areas, they will be subjected to an analysis of the degree to which the projects will reduce potential suppression costs and damage to assets.

The process of explicitly enumerating assets at risk also helps to identify who benefits from those assets. It is a premise of the fire plan that those who benefit from the protection of an asset should pay for that protection. Thus, asset stakeholders will be expected to provide financial support for those projects that provide significant benefits to their assets of concern while providing little potential for reducing suppression costs. For example, if a prefire management project primarily protects structures, local government and the affected homeowners should provide the primary financial support for the project. On the other hand, if a project primarily benefits wildlife in general, then the Department of Fish and Game, the U.S. Fish and Wildlife Service and/or a wildlife interest group should bear the major costs of the project.

The first, and major, part of this appendix addresses two basic questions: What is the value of the resources or assetsat risk to wildfire? What asset losses (economic and non-economic) result from wildfire? Where possible, estimates of asset values were made on a dollar-per-acre basis. The methodologies used, although exposed to some peer review, need further review and refinement. This will be done at the state level and as a part of the pilot projects in three ranger units.

Table 1 summarizes the assets at risk framework that has been developed for estimating fire impacts. Resource assets presented here includelife and safety, air quality, range, recreation on public wildlands, structures, timber, water and watersheds, wildlife and habitat, cultural and historic resources, and unique scenic areas. No attempt has been made to make economic estimates of the value of human loss of life or injury, although there are methodologies for estimating such values.

Table 1. Assets at Risk Framework Summary

Resource	Asset Value Basis	Level of Disaggregation	Levels of Value*	Strength of Methodology
Life and safety	Non-economic values are not quantified	By population density	National, state and local	High
Air quality	Average dollar impact from particulate matter (PM10) emitted per acre burned; non-commodity assets also exist	Air quality basins (13) and basic fuel types (2)	National, state and local	Low
Range	Dollar cost of replacement feed per acre of rangeland burned	Values by regions (8), cover types (9) and ownership classes (5)	State and local	High
Recreation on public wildlands	Average dollar loss per acre burned; non-commodity assets also exist	Statewide average by public ownership categories (5)	National, state and local	Low
Structures	Average dollar loss per home burned; non-commodity assets also exist	Statewide average	State and local	High
Timber	Average dollar loss per acre burned	Values by regions (6) and ownership categories (4)	National, state and local	High
Water and watersheds	Range of economic impacts per acre for value of increased water yields; cost of sediment removal; loss of reservoir capacity; effects on hydroelectric generation; costs of watershed rehabilitation; non-commodity assets also exist	Statewide ranges of economic impacts	National, state and local	Low to medium
Wildlife, habitat, plants and ecosystem health	Qualitative discussion of the tradeoffs in fire impacts	Statewide	State and local	Low
Other resource assets, cultural and historic resources, unique scenic areas	These non-commodity assets cannot be quantified adequately; descriptive enumeration only	Statewide (generically) or place-specific	National, state and local	Low to medium

*May or may not be cumulative.

For each of the resources, the table summarizes the value basis (i.e., the units in which fire impacts have been estimated) and the level of disaggregation (resource subtype and geographic area) of these assets. The table also indicates the levels, ranging from local to national, at which the resources are valued. The manner in which “consumers” of a particular resource value it may differ from local to state to national levels. Some of the resources protected from fire in California have value beyond national borders — for example, the scenic Lake Tahoe Basin or the old growth redwood parks of the North Coast. Again, it should be emphasized that the economic values that have been calculated are preliminary and are often highly aggregated. These estimates will be refined as fire plan implementation moves to the ranger unit level. CDF is working with the Department of Fish and Game, State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co. and the East Bay Municipal Utility District to refine our approaches to wildlife, plants, ecosystem health, watersheds and water.

The remainder of this appendix examines the manner in which generalized assets at risk will be summed across the state to identify those areas with the greatest total value of assets. These initial, coarse statewide assessments will be refined at the ranger unit level through a process that includes stakeholder participation. Finally, the appendix discusses the issue of how the costs of prefire management projects will be shared among those parties benefiting from them.

Air Quality

Introduction

Air quality is of particular importance in California, given our large urban populations and the state's topographic and meteorological characteristics, which often inhibit dispersion of air pollutants. This section examines economic values related to wildfire and air quality. Similar issues exist with respect to the air pollutants created by prescribed fires.

Suppression of wildfire provides a short-term benefit to air quality by reducing the amount of vegetative and woody material that would have burned if the fire were left unchecked. However, since fire is a natural part of California's wildland ecosystems, what we prevent from burning today may simply end up burning next year. Our success at fire suppression has resulted in a fuels buildup that contributes to the occurrence of large fires with their associated acute pollution events. Thus, our fire suppression system has in part replaced a natural background level of frequent light fires with less frequent, large, catastrophic fires. Further, large wildfires result in the burning of larger fuels that would be unlikely to burn under a natural fire regime, but instead would decompose. The result of these changes is likely to be higher net wildland fire smoke emission and the concentration of these emissions in space and time, relative to the more dispersed smoke emissions of the natural fire regime.

This report begins with a review of the mechanism of pollutant emission from wildfires and then examines the impact of such smoke emissions on a range of assets — visibility, human health, materials and vegetation, and pollutant rights. Finally, an overall estimate of marginal pollutant impact values is presented. Unlike for most of the other assets examined in this appendix, there is no meaningful way to describe the total value of the resources being protected from wildfire smoke emissions by wildfire suppression.

Fire Emission and Exposure Mechanisms

Wildland fires are categorized as an "area source" by air pollution agencies, since fires release pollutants over the area burned, rather than from a discrete "point source" such as a smokestack. There are many variables involved in determining the amount of various kinds of pollutants emitted in wildfire. These factors include fuel type and loading, moisture content, topography and weather. In general, flaming materials (such as would occur with dry vegetation or wood in daytime) produce fewer pollutants than smoldering materials (e.g., relatively moist material at night). Emissions from controlled burning are likely different than those from wildfire (Reinhardt et al. 1994).

The most prominent pollutants produced in wildfire are carbon monoxide (CO), nitrogen oxides (NOx), organic gases (OG), and suspended particulates (TSP). Of particular concern for human health are particulates smaller than 10 microns in size (PM10). Table 2 indicates Air Resources Board emission factors for wildfire. Although more research is needed, they are the best information available at this time. The USDA Forest Service recently developed a more sophisticated set of emission factors (USDA Forest Service 1995), which will be incorporated when they have been more fully documented.

Table 2. Emission Factors for Wildland Fires

	Grass and Woodland		Timber and Brush	
Pollutant	lb / ton	lb / acre*	lb / ton	lb / acre**
CO	101	202	260	3,900
NOx	0	0	4	60
OG	19	38	25	375
TSP	16	23	42	630

* assumes fuel load of 2 tons per acre
** assumes fuel load of 15 tons per acre
Source: California Air Resources Board

Table 3 shows the estimated total air pollutants emitted per year by CDF and USDA Forest Service wildfire[1], based on the factors presented in Table 2 and average annual acres burned from 1985-94. These numbers indicate that wildire is responsible for the release of significant quantities of air pollutants, totaling an average of almost 600,000 tons per year.

[1] *Does not include Bureau of Land Management, Bureau of Indian Affairs, National Park Service and wildfires inside city limits' acreage.*

Table 3. Estimated Annual Wildfire Air Pollutant Emission (1985-1994 average)

Pollutant	Grass and Woodland (tons of emissions)	Timber and Brush (tons of emissions)	Total (tons)
	CDF Fires		
CO	6,083	139,695	145,777
NOx	0	2,149	2,149
OG	1,144	13,432	14,576
TSP	693	22,566	23,259
Total	7,920	177,842	185,762
	USDA Forest Service Fires		
CO	4,457	319,125	323,583
NOx	0	4,910	4,910
OG	839	30,685	31,524
TSP	508	51,551	52,059
Total	5,803	406,271	412,075
	CDF and USDA Forest Service Fires		
CO	10,540	458,820	469,360
NOx	0	7,059	7,059
OG	1,983	44,117	46,100
TSP	1,200	74,117	75,317
TOTAL	13,723	584,113	597,836

Estimating the impacts of pollutants is difficult even for industrial point sources, since the sources and receptors are often distant from one another, with many intervening variables. For wildfire, the emission-to-impact chain of causation goes something like this. First, a fire occurs, emitting varying amounts of pollutants depending upon its size, the fuels burning, the moisture content of those fuels, topography, and meteorological conditions. Next, those pollutants are transported from the site of emission to potential receptors. The dosage of the pollutant (concentration and duration) received by the receptor will be strongly influenced by the transport distance and intervening meteorological factors. The actual impacts suffered by the receptor will depend upon susceptibility (e.g., for human receptors, age, asthma, chronic obstructive pulmonary disease, etc.).

Trying to attach economic value to the impacts of air pollutants is formidable. While some work has been done in this area, the results are limited and in many cases are difficult to translate to pollutants arising from wildfire.

Overall, the air quality impacts of smoke from wildland fire are important, especially given the fact that most air basins in the state are in non-attainment status for many pollutants, including those most closely associated with wildfire. According to RERI (1994) none of the state's 14 air basins were in attainment with state PM10 standards at the 1987 benchmark date; only half were in attainment with the weaker federal standard.

Resources Protected

Wildfire smoke emissions can affect visibility, human health, materials and vegetation, and pollutant rights. Each category is examined in turn. Finally, an overall estimate of marginal pollutant economic impacts is presented.

Visibility. Visibility relates to a person's ability to see objects in the distance and the manner in which pollutants decrease visibility. Air pollution can have significant, adverse impacts on the aesthetic assets of visibility (Chestnut et al. 1994). In the extreme, loss of visibility can affect public safety. The wildfire-related pollutant of greatest impact on visibility is particulate matter.

Analysts have defined two primary visibility categories, residential and recreational, with the former category providing the bulk of the related economic value (Chestnut et al. 1994). The values individuals place on improvements in visibility have generally been estimated through a survey method known as contingent valuation. While this method has its limitations, it provides the preponderance of the information available on the economic value of visibility.

Estimates of the value of visibility are usually based on a general improvement in air quality over the course of a year. It is not possible to translate these estimates into a value for loss of visibility for a single acute visibility impairing event such as a wildfire. Based on their own work and that of others, Chestnut et al. (1994) provide estimates of value for a 20 percent improvement in residential air quality. The estimate of value ranges from $112 per household per year to $224 per household per year, with $157 per household per year accepted as the central estimate (all figures are 1995 dollars).

For recreation assets, values for protecting visibility in parks is most often examined. Given the high level of outdoor recreation that occurs in California, and considering the presence of such unique and highly visited outdoor resources as Yosemite National Park and the Tahoe Basin, these assets, in aggregate, can be considerable. Individuals are expected to value not only the opportunity to enjoy good visibility during their own visits to parks, national forests, and other areas, but also the opportunity for others to enjoy that visibility now and in the future. Chestnut et al. (1994) found a total value of $16 per household per year for in-state residents and $9 per household per year for out-of-state residents for a 20 percent improvement in air quality (all figures are 1995 dollars). While these data indicate significant values for improvements in overall visibility in both residential and recreation areas, they cannot easily be translated to the acute visibility effects of wildfire.

Human Health Knowledge of the health effects of wildfire smoke emissions is limited. A recent study of effects of smoke exposure of prescribed burning workers recommended a health risk assessment to evaluate the likelihood of acute and chronic health effects of exposure (Reinhardt et al. 1994). These researchers conclude that the most significant pollutants for firefighter health include carbon monoxide, aldehydes, benzene, and respirable particulate. However, smoke exposure at large, intense wildfires is likely different than at prescribed fires, and different yet than the general public's exposure to smoke some distance from the fire itself. In terms of general public health considerations, respirable particulate matter appears to be the pollutant of greatest import.

Most of the particulate matter produced in wildland fire is respirable; that is, it is small enough to pass through the upper respiratory system and enter the lungs. Acute smoke impacts include eye, mucous membrane, and respiratory tract irritation, aggravation of chronic respiratory and cardiac disease, and reduced lung function (Reinhardt et al. 1994, RERI 1994). Although placed in a fairly innocuous category by OSHA, studies have shown wood smoke to have a high mutagenic and carcinogenic potential, and epidemiological studies have connected disease and adverse respiratory symptoms with particulate laden atmospheres (Reinhardt et al. 1984). However, the effects of chronic exposure to wood smoke over the long term remain uncertain.

Economic value of health impacts is most often measured by medical expenditures and lost wages. However, since this does not account for pain and suffering, such estimates represent at best a low bound economic estimate of health impacts (RERI 1994). These authors established a table of estimates for the economic value of health impacts (Table 4).

Table 4. Estimated Economic Impact of Health Effects (1995 dollars)

	Estimated Range of Impacts		
Impact	Low	Medium	High
Cough	$3.14	$7.32	$14.64
Headache	3.14	7.32	14.64
Eye Irritation	3.14	7.32	14.64
Chest Discomfort	3.14	7.32	14.64
ARD	3.14	7.32	14.64
TRRAD	23.54	48.64	73.74
MRAD	14.64	23.54	40.27
Asthma Attack	11.51	33.47	55.44

ARD = any respiratory disease days
TRRAD = total respiratory related restricted activity days
MRAD = minor restricted activity days
Source: RERI 1994.

Where air pollution causes death, placing an economic value on that loss is generally done through a "value of a statistical life" approach. RERI (1994), based on a comprehensive review of the literature and considerations of various factors, accepted a mid-range value of $4.2 million dollars for the value of a statistical life.

While these health and associated economic impact data are enlightening, they are of limited use since there are no functional relationship data available to link wildfire occurrence to the resulting levels of health impacts. Thus, we have no ability to calculate overall economic impacts.

Materials. Damage to materials from exposure to the smoke of wildland fires is related to the effects of particulate matter in soiling and discoloring structural metals, fabrics, and building materials (RERI 1994). Dose-response estimates for materials damage have been fraught with much uncertainty, making it difficult to estimate the economic impacts of smoke from wildfire. However, RERI (1994) has estimated that a one-unit reduction in PM10 (in micrograms per cubic meter) results in $3.13 (1995 dollars) benefit in saved cleaning costs per household. This estimate cannot be conveniently translated into the wildfire situation, however, since it is a measure of the benefits resulting from a change in average annual PM10 levels, not the acute, short term changes that might be associated with a wildfire.

Vegetation. Air pollution damage to vegetation, including timber, is primarily related to ozone and sulfur dioxide exposure (RERI 1994). Since these are not major components in the smoke of wildland fires, it appears that vegetation is little affected by the smoke of such fires and need be considered no further in this analysis.

Pollution Rights. In recent years, air quality regulators have moved in part to use market approaches to allocating among industrial polluters the atmosphere's limited capacity to absorb air pollutants. As a part of this approach, regulators in some air basins now allow polluters to buy and sell rights to emit specified quantities of pollutants within a given airshed. These approaches can achieve more economically efficient pollution control results than systems based on technological controls alone (Tietenberg 1985).

The Air Resources Board monitors the prices paid in exchanges of pollution rights in California air basins. Among the pollution rights traded, particulate matter is the one most relevant for wildfire. In 1993, rights for emission of approximately 45 tons per year of PM were exchanged, with prices ranging from $10,000 to $25,000 per ton per year and averaging $19,123 per ton per year (Air Resources Board 1994). PM had the highest average ton/year value of the four criteria pollutants examined in the report.

These pollution rights represent a perpetual right to emit the given quantity of pollution each year. If we annualize this value, using a 7.5percent real discount rate, the average $19,123 per ton per year perpetual pollution emission value has an annualized value of $1,434 per ton per year.

Referring to the emission factor information presentedin Table 2, grass and woodland fires emit 23 pounds of particulate matter per acre burned and timber and brush fires emit 630 pounds. Thus, if we assume that a change in wildfire emissions creates a similar value as PM pollution rights, we can estimate the economic impacts of a marginal increase or reduction in a given year's wildfire PM emissions, based on the change in number of acres burned. For grass and woodland, the value would be $16 per acre per year and for timber and brush, the value would be $452 per acre per year. Since one generally would not burn the same piece of ground more than once in a year, we can functionally cancel out the per-year unit of these variables and assume that the air pollution right cost of burning an acre is $16 for grass and woodland and $452 for timber and brush.

These values must be used carefully, however. First, not all air basins have a market in PM pollution rights, thus there would be no pollution right value for PM in such basins. In 1993, there were PM rights transactions in only three air basins, the San Francisco Bay Area, Sacramento Metropolitan, and the South Coast. However, the fact that most air basins are non-attainment for PM suggests that there may be other areas where a pollution rights value could be ascribed to wildfire PM emissions.

Looking at the Bay Area air basin, in 1992, 4,121 acres of grass and woodland and 320 acres of timber and brush burned on CDF-DPA. Using the data above, these fires emitted an estimated 148 tons of PM, with a value of approximately $211,000. In the South Coast air basin in 1992, 3,782 acres of grass and woodland and 9,601 acres of timber and brush burned on CDF-DPA. Thus, these fires emitted an estimated 3,068 tons of PM with a value of approximately $4.4 million. Totaling for these two air basins with active PM pollution rights markets, the value of wildfire smoke emissions in 1992 was approximately $4.6 million.

Greenhouse Gases. Carbon is an important contributor to the greenhouse effect. The California Energy Commission (1995) estimates an externality impact of $36 per ton (1995 dollars) for carbon emissions. Converting this value to CO emissions yields an externality impact of $15.43 per ton of CO. One could use the emission factors in Table 2 to calculate a carbon impact value for wildland fire (the results would be $1.56 per acre of grass or woodland burned and $30.09 per acre of timber or brush burned). However, the impact value for carbon is calculated on the basis of fossil fuel combustion and assumes that the carbon released to the atmosphere will not be directly re-sequestered. Since the carbon released in a wildland fire will eventually be re-sequestered in vegetative regrowth on the same site, it seems more appropriate to view the release of carbon from wildland fire as a short-term impact that does not contribute to long-term accumulation of greenhouse gasses. Therefore, it is the recommendation of this plan that carbon impact values not be calculated for wildland fire, whether the fire is prescribed or not.

Table 5. Overall Marginal Pollution Impact Values for PM10 (1995 dollars)

				Including Pollution Right Value	
Air Basin	Marginal Emission Value ($/ton)	Grass and Woodland ($/acre)	Timber and Brush ($/acre)	Grass and Woodland ($/acre)	Timber and Brush ($/acre)
San Francisco Bay Area	24,258	279	7,641	295	8,093
South Central Coast	6,441	74	2,029	74*	2,029*
South Coast	46,458	534	14,634	550	15,086
San Diego	24,593	283	7,747	283*	7,747*
Sacramento Valley	2,935	34	925	50	1,377
Southeast Desert	708	8	223	88*	223*
San Joaquin Valley	5,184	60	1,633	60*	1,633*
North Central Coast	6,441	74	2,029	74*	2,029*
North Coast	1,703	20	536	20*	536*
Great Basin Valley	125	1	39	1*	39*
Northeast Plateau	395	5	124	5*	124*
Lake Tahoe	924	11	291	11*	291*
Lake County	908	10	286	10*	286*

Unweighted Average	9,313	107	2,934	111	3,038

* indicates assumed PM10 pollution right value is zero.
Sources: California Energy Commission 1993, 1995; Air Resources Board 1994.

Rangeland

Introduction

California's 82,470,000 acres of rangeland are a critical part of the productive base of the range livestock industry in the state (CH2MHILL 1989). This rangeland crosses a wide spectrum of vegetation covertypes, from desert, to annual grasslands, to chaparral, to oak woodlands, to conifer forest. Of this area, an estimated 30,000,000 acres are actually grazed. Total annual revenue produced by the range livestock industry is in the vicinity of $1 billion (Tippet,pers. comm., 1995).

This report examines the value of the forage provided by rangelands and the loss to the rangeland owner or lessee when grazed lands burn in wildfires. When rangeland burns, assets other than forage may be affected as well, such as wildlife habitat, water quality, and air quality. These impacts are addressed in other asset sections.

Value of Forage Production from Grazed Lands

Using a market value approach, the value of forage production from grazed lands in the state can be measured by the fees paid by the livestock industry to graze these lands. CH2MHILL (1989) presents data on grazed acreage, carrying capacity, and grazing fees. Table 6, below, presents the annual value of grazing in the state, based on the data in CH2MHILL, with adjustment of grazing fees to 1995 dollars. Table 7 presents a key to the abbreviations for the covertype and ownership categories found in Table 6.

As indicated in Table 6, the annual value of grazing in the state is approximately $138 million per year. Thus, forage value represents about 13 percent of the total value of the range livestock industry's annual output. Regionally, the highest grazing value is found in the San Joaquin Valley ($54.1 million per year) and the lowest on the East Side ($1.9 million per year).

Table 6. Annual Value of Grazing in California (in dollars)

Cover Type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Total
CHP.BLM	$287	$2,851	$861	$837	$8,530	$3,230	$0	$10,269	$26,864
CHP.OP	118	1,994	1,827	130	357,576	1,788	26	7,861	371,320
CHP.PVTL	40,271	105,477	46,598	10,625	42,920	2,890	0	1,661	250,442
CHP.PVT	375,189	272,996	362,239	327,373	4,434,287	317,815	3,190	1,556,428	7,649,517
CHP.FS	120	10,663	7,749	4,143	59,668	8,457	4,243	27,408	122,451
WET.BLM	0	1,848	0	0	0	0	25,694	122	27,664
WET.OP	2,082	11,841	567	572	19,988	4,202	1,002	390	40,644
WET.PVTL	15,573	37,817	0	16,955	0	0	0	0	70,345
WET.PVT	109,043	425,525	993,443	67,792	238,308	2,494,474	450,983	36,660	4,816,227
WET.FS	0	23,226	6,393	2,902	0	5,691	2,772	1,009	41,994
OAK.BLM	2,630	4,914	3,193	3,542	17,196	55,466	0	385	87,326
OAK.OP	37	1,073	46,276	92	342,343	19,284	0	385	409,491
OAK.PVTL	464,668	44,794	43,610	0	146,090	116,821	0	0	815,983
OAK.PVT	1,972,610	2,305,505	4,129,931	2,668,246	11,786,387	15,706,696	0	87,515	38,656,891
OAK.FS	7,110	18,966	14,622	22,534	7,382	118,562	0	13,089	202,264
AGR.BLM	3,708	3,695	2,027	1,877	24,540	58,304	0	33,238	127,390
AGR.OP	1,397	3,934	167,751	350	796,479	11,454	0	5,709	987,075
AGR.PVTL	486,071	117,787	36,167	33,004	109,961	36,820	0	4,643	824,453
AGR.PVT	5,910,289	1,523,383	6,184,303	3,867,689	16,908,744	33,474,897	0	1,799,509	69,668,816
AGR.FS	1,370	43,226	1,155	585	0	15,565	0	2,757	64,658
PGR.OP	813	0	0	0	0	0	0	0	813
PGR.PVTL	0	0	0	0	0	0	0	0	0
PGR.PVT	301,093	0	0	0	0	0	0	0	301,093
PGR.FS	$0	$2,985	$4,788	$231	$0	$0	$674	$0	$8,677
CON.BLM	1,476	6,573	312	694	363	2,313	220	410	12,361
CON.OP	64	3,489	306	141	13,146	3,512	1,026	220	21,904
CON.PVTL	784,982	997,955	297,415	190,882	43,652	21,387	0	1,531	2,337,805
CON.PVT	866,705	457,732	205,487	289,489	385,166	317,253	12,976	47,508	2,582,316
CON.FS	6,798	142,115	68,172	44,199	19,638	43,361	45,552	12,450	382,287
SAG.BLM	0	176,071	358	15	0	11,697	56,819	4,486	249,444
SAG.OP	0	24,833	100	0	0	717	207,344	772	233,766
SAG.PVTL	0	162,014	7,601	0	0	3,375	0	0	172,991
SAG.PVT	0	3,021,696	184,965	6,206	13,263	759,413	611,959	3,764	4,601,266
SAG.FS	0	75,699	8,160	147	0	5,719	47,053	0	136,778
JUN.BLM	0	21,723	525	0	0	6,024	9,788	11,344	49,404
JUN.OP	0	1,968	118	0	0	71	16,095	55	18,308
JUN.PVTL	0	48,580	0	0	0	0	0	1,544	50,123
JUN.PVT	0	378,667	25,746	0	4,636	128,636	56,476	92,185	686,347
JUN.FS	0	49,560	801	0	29	2,546	18,294	1,169	72,399
DES.BLM	0	0	0	0	0	14,455	12,344	139,475	166,275
DES.OP	0	0	0	0	0	86	121,771	13,869	135,727
DES.PVTL	0	0	0	0	0	0	0	424	424
DES.PVT	0	0	0	0	0	303,166	186,472	355,694	845,333
DES.FS	0	0	0	0	0	205	102	202	508
Total	11,354,503	10,533,175	12,853,568	7,561,250	35,780,292	54,076,354	1,892,875	4,276,143	138,328,161

Table 7. Key to Abbreviations in Table 6

Abbreviation	Definition
*.BLM	land managed by the Bureau of Land Management
*.FS	land managed by the USDA Forest Service
*.OP	land managed by a public agency other than the above two
*.PVT	privately owned land
*.PVTL	privately owned land under lease
CHP.*	chaparral
WET.*	wetlands
OAK.*	oak woodland
AGR.*	annual grasslands
PGR.*	perennial grasslands
CON.*	conifer lands
SAG.*	sagebrush
JUN.*	juniper lands
DES.*	desert

Impact of Wildland Fire on Grazing Value

Wildland fire impacts rangeland by burning up the forage present on the land at the time of the fire, as well as by reducing forage production for the next two years. In some cases, however, fire can result in a net increase in forage production over time. The actual magnitude of the economic impact to the landowner depends upon the land's carrying capacity, whether the land is being grazed, the time of year at which the fire occurs, the amount of the year's forage which has already been grazed, and the intensity of the fire. When grazed lands are burned, lost forage must generally be replaced through feeding oat hay or alfalfa to the livestock (McDougald, pers. comm., 1995).

Replacement feeding costs were calculated using statewide averages for oat hay and alfalfa prices; regional data were not available (USDA Statistical Reporting Service). Prices reported for January 1995 were $85/ ton for oat hay and $123/ton for alfalfa. Transportation costs and feeding costs were each assumed to be $15/ton (McDougald, pers. comm., 1995). One animal unit month of feeding was assumed to be 800 pounds of a 60/40 mix of oat hay and alfalfa (McDougald, pers. comm., 1995).

It was assumed that the burning of rangelands would affect forage productivity for the current year plus two additional seasons (McDougald,pers. comm., 1995). We assumed that although all the standing forage would be destroyed by the fire, only half of the year's forage production would be lost because, on average, half of the forage would be consumed by livestock before the fire occurrence. The first year after the fire, forage production was assumed to be 50 percent of normal. The second year after the fire, production is assumed to be 80 percent of normal. We assumed productivity would be back to normal by the third year after the fire. These assumptions may overstate losses since fire in many cases can increase forage production over time.

Based on these assumptions, we compared the discounted three-year stream of costs of forage provision without fire to the three-year stream of costs with fire (including the costs of providing supplemental hay and alfalfa feeding). A 5 percent real discount rate was used. The difference between these two cost streams represents the loss to grazers due to fire.

We calculated these losses on a per-acre basis at the disaggregated level of region, cover type, and ownership. Table 8 presents the results when the fire affects grazed lands specifically. Table 9 presents the results for rangeland as a whole — whether grazed or not — based on the assumption that the probability of fire affecting an acre of grazed rangeland versus an acre of ungrazed rangeland is proportional to the relative fraction of all rangeland that these two categories represent. Since one does not know ahead of time whether the rangeland that will burn is grazed or not, the values presented in Table 8 are the most appropriate ones to use for fire planning. It should also be noted that grazed acres are more likely to receive fire prevention treatments than ungrazed acres, and thus may actually be at somewhat lower risk to fire than ungrazed acres.

Table 8 shows that the weighted statewide average loss when grazed rangeland burns is $24/acre. Average costs range from $4 per acre on the South Coast to $52 per acre on the North Coast.

Table 9 shows that the weighted statewide average loss when rangelands in general burn is $8 per acre. Average costs range from $1 per acre on the South Coast to $25 per acre in the San Joaquin Valley.

Recreation, Cultural and Historic Resources

Introduction

This report discusses wildland recreation and unique assets in California and how their values are affected by wildfire. Part one identifies recreation assets; part two assesses their commodity and non-commodity market values and how they are affected by wildfire.

California's 18 national forests, 17 national park units, nearly 300 state park units, and numerous county and local parks are a major recreation draw for state residents, people from other states, and citizens of other nations. Unique natural places, such as Yosemite National Park, often exert a powerful force on the imagination, and contribute to the world perception of California as the place that "has it all," not just beautiful beaches, shimmering deserts, snow-capped mountains, and fertile valleys, but some of the world's most spectacular hunting, fishing, hiking, and camping country as well. Recreation visits to California's state parks, national forests, and national parks exceed all other states in the nation (U.S. Department of Commerce, 1986). Visitation figures are important as a means of gauging just how many people visit California's wildlands and forests, and just how much money those facilities generate themselves. But this is only a part of the picture, for many tourists attracted by recreation opportunities make a significant contribution to the state economy which is not reflected in the identification of actual recreation market values. Visitors get to California by purchasing airline tickets, they stay in hotels, purchase meals and gasoline, and often do many other things besides outdoor

Table 8. Cost impact of Burning One Acre of Grazed Rangeland (in dollars)

Cover Type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Weighted Average
CHP.BLM	$3.08	$12.34	$12.96	$8.02	$17.53	$5.43	$3.61	$8.41	$9.61
CHP.OP	35.76	29.13	13.12	7.71	15.98	6.81	41.46	16.88	15.90
CHP.PVTL	33.10	27.56	13.62	8.00	16.12	6.44	48.85	15.98	19.25
CHP.PVT	33.10	27.56	13.62	8.00	16.12	6.44	39.23	15.98	14.98
CHP.FS	40.77	9.02	19.88	13.05	19.53	12.11	9.89	1.16	4.13
WET.BLM	0.00	77.94	0.00	0.00	0.00	0.00	71.69	25.56	71.50
WET.OP	80.54	102.35	65.82	66.36	65.14	80.56	501.15	87.37	76.97
WET.PVTL	76.20	96.83	77.55	62.79	75.88	94.91	590.44	102.94	81.33
WET.PVT	76.20	96.83	62.28	62.79	60.93	76.22	474.15	82.66	79.85
WET.FS	0.00	37.67	68.66	32.98	0.00	51.92	19.03	12.00	36.93
OAK.BLM	59.43	97.85	83.02	73.16	81.97	80.57	0.00	26.95	79.83
OAK.OP	80.59	122.36	49.21	35.32	30.97	54.90	0.00	18.26	33.07
OAK.PVTL	76.25	115.77	46.65	41.61	29.30	51.94	0.00	21.51	55.70
OAK.PVT	76.25	112.50	46.65	33.42	29.30	51.94	0.00	17.27	41.62
OAK.FS	124.83	64.58	58.97	49.38	155.69	47.98	0.00	1.17	27.12
AGR.BLM	173.26	97.67	80.24	108.42	117.69	93.66	0.00	60.05	85.71
AGR.OP	135.80	132.39	36.24	45.60	48.29	63.15	0.00	56.65	46.46
AGR.PVTL	117.83	121.43	37.61	46.49	49.40	59.74	0.00	53.60	85.04
AGR.PVT	117.83	121.43	37.61	46.49	49.40	59.74	0.00	53.60	55.89
AGR.FS	243.99	98.09	114.66	108.37	131.86	102.25	0.00	61.43	98.13
PGR.OP	105.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.67
PGR.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGR.PVT	99.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.98
PGR.FS	0.00	11.56	32.57	7.10	0.00	0.00	22.95	0.00	18.58
CON.BLM	6.19	5.99	8.99	7.17	15.65	11.29	7.37	9.01	6.98
CON.OP	15.97	10.31	3.55	4.24	7.91	12.68	43.29	13.02	9.31
CON.PVTL	15.11	10.70	3.34	4.40	8.21	11.99	51.00	12.32	8.21
CON.PVT	15.11	10.70	3.34	4.40	8.21	11.99	40.95	12.32	8.47
CON.FS	14.54	6.28	6.30	5.62	10.25	3.91	5.40	10.31	5.93
SAG.BLM	0.00	20.23	15.21	9.35	0.00	12.54	6.66	0.87	10.69
SAG.OP	0.00	25.97	6.99	9.78	13.83	11.57	22.24	1.37	21.41
SAG.PVTL	0.00	24.58	6.33	9.78	13.83	10.95	26.21	1.62	22.48
SAG.PVT	0.00	24.58	6.33	7.86	11.11	10.95	21.04	1.30	18.67
SAG.FS	0.00	20.57	16.28	10.34	0.00	13.02	10.49	0.00	15.00
JUN.BLM	0.00	9.68	11.22	0.00	0.00	7.35	5.75	3.20	5.91
JUN.OP	0.00	25.84	8.02	0.00	8.05	9.42	42.82	12.33	38.24
JUN.PVTL	0.00	24.45	9.45	0.00	8.05	11.09	50.45	11.66	23.65
JUN.PVT	0.00	24.45	7.59	0.00	6.47	8.91	40.51	11.66	15.84
JUN.FS	0.00	10.90	8.88	0.00	2.64	7.43	6.31	4.29	8.87
DES.BLM	0.00	0.00	0.00	0.00	0.00	3.35	2.21	1.12	1.23
DES.OP	0.00	0.00	0.00	0.00	0.00	2.31	8.25	1.11	4.98
DES.PVTL	0.00	0.00	0.00	0.00	0.00	2.73	9.72	1.05	1.05
DES.PVT	0.00	0.00	0.00	0.00	0.00	2.19	7.81	1.05	1.69
DES.FS	0.00	0.00	0.00	0.00	0.00	3.11	0.81	0.89	1.22
Wtd. Ave.	$52.45	$21.04	$23.95	$21.21	$30.93	$41.25	$10.64	$3.52	$23.59

This table measures the loss to the owner / grazer when an acre of grazed land burns. It is based on the difference between feeding the livestock forage vs. feeding them hay / alfalfa.

Table 9. Cost impact of Burning One Acre of Rangeland (in dollars)

Cover type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Weighted Average
CHP.BLM	$0.21	$1.69	$0.41	$0.29	$0.99	$1.64	$0.00	$1.24	$0.99
CHP.OP	0.04	0.26	0.24	0.01	5.29	0.12	0.00	0.13	1.74
CHP.PVTL	10.01	4.19	4.15	3.14	9.21	3.41	0.00	3.92	5.03
CHP.PVT	10.01	4.19	4.15	3.14	9.21	3.41	3.01	3.92	6.04
CHP.FS	0.06	1.88	1.39	2.14	1.49	0.92	1.14	0.84	1.21
WET.BLM	0.00	19.74	0.00	0.00	0.00	0.00	13.08	3.91	13.24
WET.OP	2.26	1.83	0.08	0.46	14.04	0.61	1.30	0.21	1.58
WET.PVTL	36.77	44.64	0.00	26.68	0.00	0.00	0.00	0.00	36.90
WET.PVT	36.78	44.65	23.93	26.67	60.93	64.01	40.18	15.74	42.23
WET.FS	0.00	10.79	17.08	6.20	0.00	7.02	3.42	2.49	8.26
OAK.BLM	3.24	10.50	2.23	2.99	3.70	13.27	0.00	4.11	6.81
OAK.OP	0.01	6.97	8.03	0.02	11.30	2.32	0.00	0.19	7.55
OAK.PVTL	41.40	35.25	20.59	0.00	24.64	50.15	0.00	0.00	35.67
OAK.PVT	41.40	34.25	20.59	21.43	24.64	50.14	0.00	8.26	31.10
OAK.FS	113.97	7.51	9.57	6.69	78.88	12.88	0.00	1.17	9.51
AGR.BLM	7.43	14.81	3.61	3.76	8.65	22.25	0.00	21.75	14.48
AGR.OP	0.77	2.91	12.07	0.19	26.51	0.97	0.00	0.67	11.69
AGR.PVTL	52.16	37.08	21.35	31.17	39.94	57.95	0.00	21.92	43.74
AGR.PVT	52.16	37.08	21.35	31.16	39.94	57.96	0.00	21.90	42.19
AGR.FS	2.93	22.72	2.85	3.75	0.00	19.96	0.00	17.68	15.82
PGR.OP	5.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64
PGR.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGR.PVT	74.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.08
PGR.FS	0.00	2.81	9.59	1.06	0.00	0.00	5.40	0.00	4.28
CON.BLM	0.35	1.14	0.30	0.21	0.31	4.12	0.64	1.64	0.74
CON.OP	0.00	0.09	0.11	0.00	0.47	0.06	1.33	0.06	0.08
CON.PVTL	3.24	2.93	2.55	2.14	3.03	8.42	0.00	3.62	2.90
CON.PVT	3.24	2.93	2.55	2.14	3.03	8.42	1.86	3.62	3.13
CON.FS	0.27	0.96	1.10	0.94	1.06	0.81	1.79	1.06	0.98
SAG.BLM	0.00	5.41	1.91	0.47	0.00	3.35	1.21	0.64	2.77
SAG.OP	0.00	1.15	0.10	0.00	0.00	0.10	1.13	0.03	0.96
SAG.PVTL	0.00	12.14	6.33	0.00	0.00	7.97	0.00	0.00	11.76
SAG.PVT	0.00	12.14	6.33	1.83	8.95	7.97	9.26	0.56	10.32
SAG.FS	0.00	5.40	4.76	0.67	0.00	2.44	2.32	0.00	3.54
JUN.BLM	0.00	2.48	2.40	0.00	0.00	1.61	1.10	2.13	1.83
JUN.OP	0.00	0.46	0.77	0.00	0.00	0.46	1.08	0.02	0.84
JUN.PVTL	0.00	5.88	0.00	0.00	0.00	0.00	0.00	2.43	5.63
JUN.PVT	0.00	5.88	7.15	0.00	2.43	4.37	8.89	2.43	4.78
JUN.FS	0.00	2.93	2.14	0.00	0.02	1.22	1.32	0.43	1.93
DES.BLM	0.00	0.00	0.00	0.00	0.00	1.03	0.27	0.48	0.48
DES.OP	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.03	0.18
DES.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
DES.PVT	0.00	0.00	0.00	0.00	0.00	2.05	5.54	0.40	0.79
DES.FS	0.00	0.00	0.00	0.00	0.00	0.82	0.07	0.14	0.16
Wtd. Ave.	$10.94	$4.93	$9.44	$7.26	$16.35	$24.64	$1.86	$1.19	$8.49

This table measures the loss to the owner/grazer when an acre of rangeland burns. It is assumed that the amount of such rangeland that is grazed is directly proportional to the amount of all such rangeland that is grazed.

recreation. Non-residents constitute a significant portion of recreational use of the state's wildlands. The California Department of Tourism estimates that non-residents accounted for 46 percent of the 48 million trips takenin California during 1983-84. Nearly 3 million non-resident trips are estimated to have had outdoor recreation as the primary purpose and consisted of visits to the state's parks and forests (Keye, Donna and Pearlstein Inc., 1985).

Recreation and Unique Areas in California

General Wildland Recreation. Outdoor recreation is typically defined in terms of Recreation Visitor Days (RVDs). One RVD represents 12 hours of participation in any recreation activity. According to information obtained from the relevant agencies, annual forest and rangeland recreation on state and federal lands has averaged over 112 million RVDs in recent years according to data collected from the relevant agencies (Table 9). National forest use amounted to 71.5 million RVDs, national parks 19.8 million RVDs, state parks 12.8 million RVDs, and Bureau of Land Management lands about 8 million RVDs.

National forest recreation in the state is estimated to represent one quarter of all national forest recreational use throughout the U.S., although the 20 million acres of national forest land represent only 11 percent of the national total. Recreation on national forests is distributed among the 18 national forest units administered in the state.

The National Park Service administers 22 units in California, although not all of these provide wildland recreation opportunities. Yosemite National Park is the most visited national park in the state and one of the top national park destinations in the nation. Internationally renowned, it draws thousands of visitors from outside the United States each year.

The Bureau of Land Management manages 17 million acres of California lands. Off-highway driving and camping are the most popular activities.

The state park system contains nearly 300 units and covers almost 1.3 million acres. Anza-Borrego Desert State Park in San Diego County accounts for 553,000 acres, or nearly half of the total state park system acreage. Average size of the other parks is 5,000 acres. About one-half of the 300 units, or 1.2 million acres, support some form of wildland recreation.

The central Sierra region is the most heavily used recreation area in the state. This is a function of the large number of recreation opportunities on national forests and parks (including Lake Tahoe) and the close proximity of major population centers. Southern California also supports a high number of RVDs, particularly on national forests. Southern California has less national forest acreage (about 1.8 million acres) than any other region except the North Coast Region (0.9 million acres). Yet the amount of national forest use is higher than anywhere else in the state and 30 times greater than the North Coast.

Recreation on lands other than those owned by the state or federal government is more difficult to assess because there is little coordinated record-keeping and few available records. These other lands include private recreation facilities, such as campgrounds, hunting clubs, public utility lands, and county, city and regional parks.

Wildlife-Oriented Recreation. Wildlife-oriented recreation is a significant and high-value portion of wildland recreation. As indicated below in the section on effects of wildland fire on wildlife, fire effects are generally negative for fisheries, but can be positive, negative, or neutral with respect to other wildlife. The next few paragraphs illustrate the importance and value of wildlife-oriented recreation in California.

One partial measure of the value of wildlife-oriented recreation is expenditures for fishing and hunting licenses. In 1994, almost 2.4 million sportfishing licenses were issued in California, along with close to 900,000 sportfishing stamps. In total, these generated almost $4 million in license and stamp revenues. Hunting is also a popular recreational activity. More than 354,000 hunting licenses and 828,000 tags and permits were sold in the state in 1994. These sales generated about $14.6 million in revenues to the state. In total, fishing and hunting generated $18.6 million in licensing revenues.

Wildlife-oriented recreation generates some of the highest user values of any recreation form, according to the USDA Forest Service (1990). Based on this source, a wildlife and fish user day (WFUD) in California is valued at $77 for fishing, $40 for hunting, and $88 for non-consumptive wildlife use (all figures in 1995 dollars).

A survey sponsored in the mid-1980s by the Department of Parks and Recreation indicated that more people may participate in non-consumptive types of wildlife recreation than do actual hunting and fishing, such as bird watching or wildlife photography (California State University 1987). Out of the survey sample of 2,526 people statewide, nearly 34 percent said that they spent some or most of their leisure time outdoors and participated in at least one non-consumptive wildlife activity. Another 32.5 percent indicated they spent some or most of their leisure time outdoors and participated in at least one non-consumptive wildlife activity and also fished and/or hunted. Only about 3 percent stated they spent some or most of their leisure time outdoors, and hunted and/or fished, but did not participate in non-consumptive wildlife activities.

Archaeological and Historical Sites. Archaeological and historical sites represent another type of unique resource found in California. These include prehistoric Indian village sites, petroglyphs, pictographs (rock paintings), midden deposits, human burial grounds, caves, hunting blinds, and bedrock milling sites. Historic sites include buildings and structures of historical significance (such as Fort Ross, Bodie, etc.), Gold-Rush-era mining sites, wagon roads and trails, and cemeteries. Many of these historic resources contain irreplaceable assets which are at risk from wildfire. Some of these are situated on national and state park lands and directly contribute to the recreational use of a park. Most sites, however, have little recreation value as the public is often discouraged from unsupervised visitation due to relic hunting, site vandalism and other impacts. These sites have unique values in addition to contributing to recreation use of forest and range lands.

As of 1995, there are over 100,000 recorded archaeological sites in California; 59,000 of these are on federal lands, 33,000 are on private or other lands, 6,000 on state lands, and 12,000 are located on county, city or special district properties (California Office of Historic Preservation 1995). The California Office of Historic Preservation (1995) has estimated that approximately 100,000 additional unrecorded (undiscovered) archaeological sites exist within the state. This latter group is most at risk from wildfires since their locations are not known, and consequently difficult to protect during fire suppression activities. Additionally, California has 85,000 recorded historic buildings, most of which are situated in wildlands. This figure does not include historic districts in cities, which are excluded from this assessment. It is primarily the 85,000 structures in rural (wildland) locations that are at risk from escaped wildfires in California.

Value of Recreation and Unique Areas in California

USDA Forest Service economists have estimated a market value for each RVD within various recreation categories (USDA Forest Service 1990). The 1995 market value of one RVD is as follows: winter sports $49.86; resorts $20.52; wilderness $16.46; camping, picnicking, swimming $10.10; mechanized travel and viewing scenery $10.31; hiking, horseback riding, and water travel $13.60; and other recreation activities except wildlife and fishing $65.89. These figures were derived from 1989 data (USDA Forest Service 1990:18-19) and converted to 1995 dollars using the GNP deflator. A weighted average 1995 market value of $13.26 per RVD was estimated for this assessment. This value is only a partial measure of the value of recreation to the state.

Table 10 applies this value to recreation on California public lands to estimate the total and per-acre annual value of the recreation on these lands. Total annual recreation values are estimated at almost $1.5 billion for the four ownership categories. The value ranges from $6 peracre on BLM lands to $141 peracre on state park system lands. Again, it should be emphasized that these are low-bound estimates of the value of public lands recreation in the state. For example, Goldman and Gates (1986) calculated the total spending by wildland recreationists in California to be $4.9 billion, which resulted in $17.3 billion in gross output, $8.2 billion in regional income, and accounted for approximately 207,000 full-time jobs. There is no question that recreation users in California make a significant contribution to the state's economy.

We also estimated the average recreation values lost when an acre of wildland burns. Wildfire does not totally destroy the recreation value of lands that are burned. For example, consider the interest that was generated after the huge Yellowstone fires of 1988. Also, if a person avoids recreating on a given area because it has burned, he or she may be able to enjoy a similar recreation experience on another, unburned area. Of course, once an area burns in a severe fire, it may take years for it to return to its former condition. To what degree these assets are affected by wildfire is a complicated issue. For some recreation use, such as winter sports (e.g., skiing), wildfires do not seem to cause a significant decrease in recreation use of an area. The recreation use is sometimes improved by opening

Table 10. Estimated Forest and Rangeland Recreation Values in California (1993-94 average)

Landowner	Acres (millions)	RVDs (millions)	Dollars per RVD*	Total recreation value in dollars (millions)	Recreation values (/acre)	Recreation value lost per acre burned
National Park Service	4.7	19.8	13.26	263	56	42
USDA Forest Service	20.4	71.5	13.26	948	46	35
Bureau of Land Management	17.1	8	13.26	106	6	5
State Park System	1.2	12.8	13.26	170	141	107
Total in California	43.4	112.1		1,486	34	26

*$13.26 figure is a weighted average calculated in 1995 dollars.
Source: Listed agencies.

up new areas for expanded skiing opportunities. However, overall, statewide recreation use is significantly degraded by wildfires, particularly due to the direct cost of replacing recreation facilities and lost revenues during time of closure, and this effect is realized in millions of lost recreation dollars annually.

We estimated the recreation use value lost when an area burns by assuming that 15 percent of its recreation value is lost during the first year after the fire and that the percentage of value lost decreases to zero in a straight line over a 10-year period. Discounting this stream of losses to the present yields an average value loss of $10.04 per RVD for a burned area. Applying this value to Table 9 yields an average statewide loss of $26 of recreation use value per burned acre of public lands. The loss per acre varies from $5 on BLM lands to $107 for state park system lands.

We also wish to illustrate the damage wildland fire can cause to recreation facilities. The 1993 Green Meadow Fire burned 38,000 acres in the Santa Monica Mountains National Recreation Area (NRA). This NRA is composed of National Park Service lands, four state parks, and privately owned lands. The fire burned numerous bridges along trails, signs, recreation structures, and a pumphouse which provided water to the five campground sites. The total cost of repairing or replacing these facilities, removing hazard trees, and cleaning up campground facilities and recreation trails was $458,549. An additional $33,614 in lost campground revenues resulted from closure of recreation facilities.

Certain unique areas in California, such as significant scenic areas and major sites of archaeological or historical interest, also attract tourism and contribute to recreation values. These too are extremely difficult to quantify, but they contribute a sizable portion of the recreation value generated at state, local and national parks, and national and state forests. Examples where historical features represent a primary attraction to recreation use include the reconstructed Coast Miwok Village at Point Reyes National Seashore, Patrick's Point State Park with its reconstructed Yurok Village, Indian Grinding Rock State Park, the reconstructed, early-19th-century Russian fortress at Fort Ross, Vikingsholm at Emerald Bay in Lake Tahoe, and the standing ruins of a historic mining town at Bodie. There are numerous other examples where California's significant cultural sites contribute to its recreation markets.

The 1987 Case Fire provides an example of how unique assets are at risk to wildland fire. This fire resulted in significant damage to a prehistoric archaeological site, an ancient Indian village on a ridgetop. The site was bulldozed by firefighters during the construction of a fuelbreak on the ridgetop. The bulldozer crew knew of the site's location and attempted to avoid it but a change in the fire behavior put the lives of the crew in jeopardy. The dozer operators were forced to make a wide clearing to escape from the flames. In doing so, the archaeological site was badly damaged. CDF was required to conduct a rehabilitation and data recovery project at the site which cost a total of $12,310. While the direct cost of this damage is relatively low, it is important to emphasize that these costs do not adequately express the social value of the damage done to this cultural resource. These types of losses are incalculable.

Structures

Loss of structures is one of the more emotionally gripping and economically significant impacts of wildland fire in California. Statewide, there are an estimated one million housing units within California's wildlands or the wildland/urban interface. Approximately 500,000 of these housing units are owner-occupied, single-family homes with an average replacement cost of $140,000. Taken as a whole, these housing units have an estimated replacement cost of approximately $107 billion.

Based on fire records for 1985-94, an average 703 homes are lost per year to wildland fire in California. It should be noted, however, that the number of homes lost varies significantly from year to year. Housing values typically range from $15,000 on up, with the median, owner-occupied single-family home valued at $140,000 (excluding land value). Since the value of the homesite is little affected by wildfire, only the value of structures and contents should be considered. Discussions with insurance and fire officials indicate that the average market value of a home's contents is 20-25 percent of the replacement value, or about $35,000 per home. Thus, as a first approximation, the median house and contents are valued at an estimated $175,000.

When insurance claims are filed for homes lost to wildland fire, insurance companies face costs to process claims. The overall cost of operating insurance programs is estimated to be 45 cents per dollar of premium. However, this represents the average of all operating costs for an insurance company, not the marginal cost of handling a claim. As a rough approximation, it is estimated here that the transaction cost to insurance companies to settle a claim is 1 percent of the claim amount, on average.

In addition to insured property loss, homeowners also face a significant loss of intangibles in a house fire. While these losses are difficult to quantify and value, they should be considered in the evaluation of the effects of wildland fire on homeowners. As an approximation, we will assume that the average homeowner faces an uninsured loss of $10,000 when his or her home is lost to wildfire.

Additional costs associated with the loss of homes to wildland fire include disruption of utilities, transportation, and other public services. In addition, there are lost wages, costs of temporary shelter, and other costs that cannot be captured easily. We will assume that these costs average $10,500 per house lost to wildland fire.

Table 11 summarizes and totals the above-described costs. Total average annual costs statewide associated with loss of homes to wildfire is $163,271,750, or $232,250 per home.

Table 11. Estimated Average Annual Losses Due to Destruction of Homes by Wildland Fire

Category	Loss Amount
Dwellings and contents lost: 703/year @ $140,000 each	$ 98,420,000
Contents valued at 25 percent of dwelling	24,605,000
Total home and contents loss (equals insurance claim amount)	123,025,000
Insurance company transaction cost	
1 percent of claim cost or 1 percent of $123,025,000	1,230,250
Uninsured losses	
Intangibles: 703 dwellings/year @ $10,000 each	7,030,000
Other improvements on site: 25 percent of home loss or 25 percent x $98,420,000	24,605,000
Total uninsured losses	31,635,000
Disruption costs: 703 dwellings/year @ $10,500 each	7,381,500
Total loss to homeowner and others	$163,271,750

Timber

Introduction

This section estimates the effects of stand-replacing fires on the value of sawtimber in California. The data available allowed quantifying only direct, near-term effects of fire in economic terms. The indirect, long-term effects of stand replacing fires such as altered soil characteristics and forest successional patterns were not considered in this analysis. Indirect effects of non-stand replacing fires such as reduced health and disease susceptibility were not considered in this analysis of stand replacing fires. The analysis considered timberlands[2] available for harvest, excluding reserved lands and lands that did not meet the definition of timberland.

Four ownership categories, five inventory regions, and two forest types within one of the inventory regions, formed the basis for quantifying fire losses on timberlands

[2] *Timberlands as used here denotes land capable of growing at least 20 cubic feet of commercial timber species per acre per year.*

with different legal and biological characteristics. Ownership categories consisted of:

- National forests
- Other public lands owned by the Bureau of Land Management, individual counties and the state
- Forest industry (private holdings 5,000 or more acres)
- Non-industrial private (private holdings less than 5,000 acres)

The five relevant inventory regions, as defined by the Forest Inventory and Analysis (FIA) project of the USDA Forest Service, are:

- North Coast (Del Norte, Humboldt, Mendocino, and Sonoma counties)
- Northern Interior (Siskiyou, Modoc, Trinity, Shasta, and Lassen counties)
- Sacramento (Butte, Colusa, El Dorado, Glenn, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Sierra, Sutter, Tehama, Yolo, and Yuba counties)
- San Joaquin and Southern California (Alpine, Amador, Calaveras, Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Madera, Mariposa, Merced, Mono, Orange, Riverside, San Bernardino, San Diego, San Joaquin, Stanislaus, Tulare, and Tuolumne counties)
- Central Coast (Alameda, Contra Costa, Marin, Monterey, San Benito, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, and Ventura counties)

The statistical limitations of the non-spatial timber inventories used in this analysis precluded estimating meaningful distinctions between forest cover types in most cases. The North Coast region was the exception: the presence or absence of redwood trees was used to distinguish between the coastal and interior forest types within this inventory region. Table 12 summarizes timberland acreage by cover type/region and ownership category.

Table 12. Acres of Timberland by Ownership and Inventory Region/Forest Cover Type

	Ownership				
Region/Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast/ Redwood+ Douglas-fir		114,000	566,000	622,000	1,302,000
North Coast/ Interior Mixed Conifer	619,000	149,000	735,000	808,000	2,311,000
Northern Interior	3,190,000	126,000	1,757,000	580,000	5,653,000
Sacramento	2,526,000	70,000	935,000	708,000	4,239,000
San Joaquin and Southern California	1,898,000	50,000	167,000	303,000	2,418,000
Central Coast	53,000	8,000	24,000	255,000	340,000
All Regions	8,286,000	517,000	4,184,000	3,276,000	16,263,000

Using the FIA inventory data and national forest inventory data, Table 13 presents the average timber volume per acre in each ownership and cover type category. In the next step of the analysis, multiplying current timber market prices from the state Board of Equalization with average volume estimates from Table 13 and timberland acreage from Table 12 resulted in an estimate of total standing timber value, in dollars (Table 14). Table 15 presents standing timber values on a per-acre average basis. Finally, historical records of fire damage provided estimates of the financial loss in timber values per acre resulting from a stand replacing fire (Table 16), based on an estimated loss of 65 percent of value from standing timber value.

The sections below further explain the methodology used to derive the data presented in Tables 12-16.

Table 13. Average Volume of Sawtimber (board feet, Scribner rule) Per Acre, by Ownership and Inventory Region / Forest Cover Type

	Ownership				
Region / Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All Ownerships
North Coast Redwood / Douglas-fir		22,918	23,053	21,365	22,235
North Coast / Interior Mixed Conifer	21,550	17,002	8,788	6,457	11,921
Northern Interior	11,670	9,821	8,255	7,405	10,130
Sacramento	22,200	14,411	14,576	11,279	18,566
San Joaquin and Southern California	20,120	9,410	17,872	3,913	17,712
Central Coast	10,500	11,626	26,976	24,008	21,821

Table 14. Total Value of Timber (millions of dollars), by Ownership and Inventory Region / Forest Cover Type

	Ownership				
Region / Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast / Redwood+Douglas-fir		$1,371	$7,773	$7,391	$16,535
North Coast / Interior Mixed Conifer	5,998	1,330	3,848	2,902	14,078
Northern Interior	14,513	495	5,423	1,638	22,069
Sacramento	24,237	502	5,921	3,698	34,358
San Joaquin and Southern California	11,469	165	984	415	13,033
Central Coast	326	47	409	3,833	4,615
All Regions	$56,543	$3,910	$24,358	$19,877	$104,688

Table 15. Per-acre Value of Timber (dollars per acre), by Ownership and Inventory Region / Forest Cover Type

Region / Forest Cover Type	Ownership				
	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast / Redwood+ Douglas-fir		$12,028	$13,733	$11,883	$12,700
North Coast / Interior Mixed Conifer	9,690	8,923	5,235	3,591	6,092
Northern Interior	4,549	3,932	3,086	2,825	3,904
Sacramento	9,595	7,178	6,333	5,223	8,105
San Joaquin and So. California	6,043	3,306	5,894	1,369	5,390
Central Coast	$6,158	$5,813	$17,035	$15,030	$13,574

Table 16. Estimated Loss, in dollars per acre, of Timber Resulting from a Stand-replacing Fire, by Ownership and Inventory Region / Forest Cover Type

Region / Forest Cover Type	Ownership				
	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast / Redwood+ Douglas-fir		$7,818	$8,926	$7,724	$8,255
North Coast / nterior Mixed Conifer	6,299	5,800	3,403	2,334	3,960
Northern Interior	2,957	2,556	2,006	1,836	2,538
Sacramento	6,237	4,666	4,116	3,395	5,268
San Joaquin and Southern California	3,928	2,149	3,831	890	3,504
Central Coast	$4,003	$3,778	$11,073	$9,770	$8,823

Timber Volume

The most recent FIA inventory data, 1,150 plots measured in 1985, formed the basis for the standing volume estimates in this analysis, except for the national forests. The standing volume estimates were derived by adding the per-acre expansion of individual tree volume estimates on each plot, and adding all plots and their acreage expansion factors. National forest timber volume data is based on individual forest inventory data, as compiled inUSDA Forest Service publications.

Timber Value

Timber values in dollars came from the State Board of Equalization's market price schedules for the major commercial timber species in the state, by regions. Weighting the timber volume estimates by tree species with their respective estimated acreages provided an accurate current market value of the estimated standing inventory. Table 14 shows the value of the estimated total volume of standing timber in each region and ownership category. These values are valid only to the extent that sellers are price takers; the analysis did not consider the price-depressing effect of releasing large amounts of timber on the market. Table

15 shows the per-acre value of the standing timber in each region and ownership category. It resulted from dividing the total value estimates in Table 15 by the estimated acreage in each region and ownership category in Table 13.

Value Loss after Fire

The impact of fire on timber value was expressed in terms of the dollar value destroyed on the average acre in a stand replacing fire. The analysis included the following assumptions about timber value loss:

- A stand replacing fire will result in a total loss of 30 percent of the standing merchantable board foot volume. Although immediate salvage can theoretically recover close to 100 percent of the green volume, a delay of 6 months or more before salvage can be undertaken is common. The 30 percent value loss is an applicable figure for both the 1987 Stanislaus fire and the 1991 Fountain fire. The remaining 70 percent of the merchantable volume, although reduced in value, will be fully recovered through salvage harvests.
- Harvest values of salvaged timber are approximately 50 percent of green tree values. This overall estimate came from the state Board of Equalization's green harvest and salvage harvest value schedules.

Based on these assumptions, only 35 percent of the prefire timber value (70 percent of volume times 50 percent of value) can be captured after a stand replacing fire. Thus, 65 percent of the value is lost. Table 16 shows the estimated dollar value per acre lost as a result of a stand replacing fire. The figures in Table 16 were derived by calculating 65 percent of the per acre value estimates in Table 15.

Water and Watersheds[3]

Introduction

Water is both an element of the environment and a commodity. Water rights and the facilities to harness water are real property. The value of water is expressed in terms of its beneficial uses. But how much water supply does California have, what is it used for, and what is its overall value to the state? And given that water is a valuable resource, how does wildfire threaten the beneficial uses of the state's waters?

Pacific storms in the winter months and mountains tall enough to make them release their moisture bless California with an ample, if maldistributed, water supply in most years. Average statewide precipitation is about 23 inches and most of it (about 60 percent) is used by native vegetation or lost by evaporation. Estimated average annual runoff amounts to about 71 million acre-feet. This water is first used to maintain healthy riparian ecosystems in California's rivers, and eventually much of it is also used for urban and agricultural supply. The available

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[3]*The department is working with the State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co. and East Bay Municipal Utility District to refine our approaches to water and watersheds.*

surface water supply totals 78 million acre-feet when out-of-state supplies from the Colorado and Klamath Rivers are added.

California uses 6 million acre-feet annually to supply urban users with residential, commercial and industrial water to support a population of over 30 million and the eighth largest economy in the world. After capture, storage, treatment, and distribution, retail customers pay on average $465 an acre-foot for this water — an annual retail value approaching $3 billion. California uses an additional 24 million acre-feet annually to support irrigated agriculture. At an average, unsubsidized value of $60 an acre-foot at the farm, this water has a value of about $1.5 billion. California also dedicates 24 million acre-feet to environmental uses. Most of this water runs its natural course through the state's river systems. Some of it is stored and released during the dry season to improve water quality in the Delta and other similarly environmentally sensitive areas. Assigning a value to this mix of wet and dry season water is problematic, but a value of $40 an acre-foot for this water would equate to about a billion dollars.

Water has many other non-consumptive values to Californians as well. For example, falling water is used to generate large amounts of hydroelectric power. In an average year, California produces about 40,000 gigawatt-hours of hydroelectric power with a value of approximately $1.6 billion. Additionally, water provides recreational opportunities and scenic beauty throughout much of the state. Conversely, excessive amounts of water can cause serious problems in many areas of the state. Floods may lead to fatalities and damage extensive amounts of personal property. A multitude of flood control structures and other measures are used to mitigate this threat. Large, intense wildfires that significantly alter hydrologic regimes and increased erosion and sediment loads can adversely affect the value of surface runoff water. Smaller, lower intensity fires that do not produce these impacts are generally not a problem. Indeed, frequent, low intensity fires are a natural part of many ecosystems. They reduce the incidence and severity of large, intense wildfires and produce the most stable watershed conditions in the long run.

California's watersheds are fire-adapted, but fire suppression is still critical to protect life and property. Total fire suppression, however, can be detrimental in the long-term to fire-adapted environments. Aggressive fire suppression without an equally aggressive program of fuels and fire hazard reduction leads to larger, more intense fires, which is ultimately detrimental to both environmental and commodity uses of water.

Since the work presented in this section was completed, we have initiated a cooperative process with the State Water Resources Control Board staff and others to refine the methods and data utilized here. An updated water and watersheds assets report will be issued upon completion of this process.

Types and Magnitudes of Impacts

Large, intense wildfires often have a negative effect on water quality and beneficial uses as a result of increased erosion and, consequently, sedimentation. Sediment increases are measured in terms of additional cubic yards of material delivered to streams and transported to places of deposition. Additional sediment storage can alter a stream's form and function in a deleterious manner. Water quality effects of wildfires are usually measured as increases in total dissolved solids (TDS) and total suspended solids. Large, intense wildfires may also increase runoff and peak flows. Increases in runoff are expressed in additional acre-feet of water.

The magnitude of these impacts in a given watershed can vary greatly with a number of factors, including type and condition of the vegetation, type of soil and its moisture content at the time of the fire, level of heat generated by the fire, slope, aspect, proximity to the nearest watercourse, and the timing and intensity of post-fire storms (USFS 1979a). Without the detail of specific cases, fire related watershed impacts can only be described in general terms.

Accelerated erosion usually leads to accelerated sedimentation. Experience on the Stanislaus National Forest, for example, indicates large, intense wildfires produce an average of 20 to 50 tons per acreper year of erosion for the first two years following burning (J. Frazier and A.Janicki, Stanislaus National Forest, pers. communication). Of this amount, about half, or 10 to 25 cubic yards per acre per year of the eroded material, reaches a stream and becomes sediment. In contrast, unburned forest lands have erosion rates of less than one ton per acre per year and less than a fifth reaches a stream to become sediment. Similarly, estimates of hillslope erosion on the Shasta-Trinity National Forest following extreme wildfire events in 1987 on 50 percent slopes with no remaining ground cover ranged from 10 to almost 40 cubic yards per acre, depending on the soil type present (Miles and others 1989). Monitoring with silt fences installed in swales on burned areas of the Shasta-Trinity with granitic soils having very little ground cover and steep slopes produced sedimentation rates up to 12.2 cubic yards per acre (Miles and others 1992).

Experience in chaparral is somewhat different (DeBano 1989). Erosion and sediment production in chaparral is more variable than in forest lands for both unburned and burned conditions. In unburned watersheds, sediment was found to collect in debris basins at rates ranging from 0 to 109 tons per acre per year[4]. The range is great due to the tendency for sediment mobilization only during infrequent large storms. In burned chaparral watersheds, sediment has been collected at rates from 0 to 312 tons per acre per year (McIlvride 1984). Recently burned chaparral watersheds generally yield 6-35 times more sediment than their unburned counterparts and average a 10-fold increase (Davis 1980). Hillslope erosion rates following burning have been found to range from less than one ton per acre per year to more than 200 tons per acre per year, with slope being a critical factor in determining the amount of erosion that occurs. As with forest lands, erosion rates are high immediately after burning, but generally return to prefire levels within a few years. This is not the case, however, for steep areas where shallow-seated landsliding is the dominant erosional process. For these chaparral covered areas, the dominant window of susceptibility is 6 to 10 years

[4] *Various studies have reported erosion in different units; a ton can be assumed to be approximately one cubic yard.*

following fire when total root biomass is lowest (Rice and others 1982). In contrast, burned grasslands develop a vegetative cover so quickly that increases in erosion and sedimentation rate are generally negligible.

Large, intense fires can also have an adverse impact on water quality (USFS 1979b). Forested watersheds generally produce water with very low TDS (<50 mg/l) and low turbidity (<1 NTU). The quality of water produced from undisturbed chaparral lands is generally lower and more variable. Intense burns can cause large increases in TDS and turbidity on forest and chaparral covered areas, particularly during storm periods. For instance, Cohen (1982) found increased concentrations of nitrogen and suspended sediment in Milliken Reservoir (Napa County) resulting from the first large storm following the Atlas Peak wildfire. Nitrate concentrations were elevated above background levels during the first winter, but did not reach levels detrimental to domestic water usage. Cohen concluded that watersheds with higher nitrate background levels and similar influxes of nutrients as occurred in Milliken Creek could cause nitrate levels to approach the recommended health limit.

Increased water yield is another potential impact of large, intense wildfires. Where 75 percent to 100 percent of the vegetative cover is removed, runoff increases average from 0.1 acre-foot per acre of burned watershed for basins receiving 15 inches of mean annual precipitation to 0.8 acre-foot per acre burned for watersheds receiving 40 inches of mean annual precipitation (based on Turner 1991). Studies of shrub recovery after prescribed burning have found that the canopy reaches the 75 percent cover or 100 percent maximum evapotranspiration level in about 8 years after burning, and that the season of burning significantly affects canopy recovery (Lampinen 1982). By extension, the wildfire-caused increase in runoff might be expected to decline to near zero over a similar period of time. In forested areas, water yield increases are minimal until basal area loss to fire exceeds 50 percent (Potts and others 1989).

The additional water yields that result from catastrophic wildfires, however, are generally considered to have little value for water supply and hydroelectric energy generation. Almost all of the additional runoff occurs during the wet season and must be regulated for dry season use by surface reservoir storage (Ziemer 1987). Typically flows increase during large storm events when water is often passed through reservoir catchment systems because of flood management concerns. Additionally, the added water yield does not contribute to a dependable water supply or firm energy capacity, since the additional water is only a very temporary supply.

Peak flows, or maximum instantaneous discharges, are also increased by large, intense wildfires. In Central and Southern California watersheds, it is estimated that peak flows will often increase about 2.5 times over pre-burn conditions with intense burning conditions (R. Blecker, Los Padres National Forest, pers. comm.). Sinclair and Hamilton (1955) found that stormflow increased threefold to fivefold on a burned California chaparral watershed during the first rainy season following wildfire. Rowe and others (1954) reported increases in peak discharge that varied from 2 to 45 times normal, depending on storm size, in the first year following wildfire. Nasseri (1989) used the Stanford Watershed Model to predict the impact of wildfire on a Southern California chaparral covered watershed. This simulation indicated that a moderate storm would produce a 200percent increase in runoff and the frequency of flooding increased dramatically. Peak flow increases in intensely burned forested watersheds may be less dramatic, particularly in basins that are wholly or partially snow-dominated (B. McGurk, USFS Pacific Southwest Research Station, Albany, pers. comm.).

Water Uses at Risk and Their Value

The beneficial uses of water as a commodity include: agriculture, urban (including residential, commercial and industrial), hydroelectric power generation, recreation, and rearing habitat for commercial and sport fisheries (see Table 17). Water also has many non-commodity beneficial uses, including aquatic and riparian habitat for non-commercial species of plants and animals, and aesthetics or scenic beauty.

Water prices vary widely in California based on the source of the water and the region and type of use. The value of the water yield that can be readily converted to water supply ranges from zero in water rich areas of the state to about $2,500 per acre-foot in critically water short locations that remove salt from brackish or sea water, such as the City of Morro Bay[5]. Water values north of the Tehachapi Mountains range from $40 to $120 an acre-foot, while south of the Tehachapis values range from $300 to $600 an acre-foot. These are current values, based on estimates that assume available water can be delivered to willing customers.

Table 17. Water Values in California

Beneficial Use	Unit	Market Value	Value (Non-Market)
Urban - Northern 2/3 of California	Acre-feet	$40-120	
Urban - Southern 1/3 of California	Acre-feet	$300-600	
Agriculture	Acre-feet	$3-252	
Hydropower generation	Acre-feet	$0-320	
Fisheries: Commercial Sport	 $/lb Rec-visitor days	 $1.30 $75	
Recreation	Rec-visitor days	>$12	
Aquatic habitat for non-commercial species			X
Aesthetics			X

On average, California uses about 30 million acre-feet (maf) per year of surface water for agricultural and urban purposes. About 5 maf derived from the Colorado River is fed by watersheds outside the state. The remaining 25 maf represents the total average annual consumption of water derived from watersheds within California. Based on regional averages found in the California Department of Water Resources' updated Water Plan (CADWR 1994), this water has a statewide unit

[5] *Despite the high cost of facilities and energy for delivery, imported water would likely cost less, but is not yet available.*

value ranging from $3 to $252 per acre-foot[6], with an average of $60 per acre-foot. The total annual value of this water is $1.36 billion.

Water often has a high value for hydropower production. For example, in 1987 Romm and Ewing estimated the power generation value of water from national forests in California to range between zero and $320 an acre-foot. Water that cannot be run through a hydropower generation facility due to timing or location is worth zero from a hydropower perspective. Water with the highest possible usable head that can be run through one or a sequence of generation facilities is the most valuable. California hydropower generates an average of 40,000 gigawatt-hours annually. The value of this power at 4 cents per kilowatt-hour (M. Johanas, CA Energy Commission, pers. comm. is about $1.6 billion. This represents a minimum value and does not include the premium paid for peaking power.

Floods, like fire, are a major problem in California. Billions of dollars have been invested over the past several decades, and millions are spent annually on flood control. Fire related increases in flood magnitude can add substantially to flood damage and repair costs. Large, intense burns make local flooding worse by elevating peak flows and adding large amounts of damage-causing debris to flood torrents.

In Northern California, intense wildfires commonly burn in watersheds with tributaries containing important spawning and rearing habitat for anadromous fish. The value of these fisheries must be considered in terms of both commercial and sport fishing. Decreasing trends in the number of salmon observed in Northern California over the last several years have caused widespread concern about the long-term viability of several species. For example, the California Department of Fish and Game recently asked the State Board of Forestry to list coho salmon as a sensitive species. The number of salmon commercially caught in Northern California from 1989 to 1991 averaged only 1,156,000, with a value of approximately $1.5 million (USFS 1993). In terms of the value of sport fishing, the USDA Forest Service (1990) reported that the value of a fisherman day in California is $74.07 (adjusted to 1995 dollars).

Water-related recreation has become an integral part of society's needs. Reservoirs, natural lakes, and streams can be adversely impacted by large, intense wildfires. Water rafting is estimated to generate just over one million visitor days annually statewide (CADWR 1994). Rugged natural beauty and some of the most renowned fishing streams in North America attract over 10 million people annually to the state's North Coast region alone. The recreational opportunities provided by reservoirs generate enormous benefits to California's economy. In 1985, an estimated $500 million was spent on water-related activities in the Delta and major reservoirs. The estimated 7 million visitors to the Sacramento-San Joaquin Delta generated an estimated $125 million; the 6.6 million visitors to the 12 State Water Project (SWP) reservoirs and the California Aqueduct brought in an

[6] Regional values of agricultural water include: North Coast-$3 per acre-foot, Sacramento-$12, Colorado River-$12, Central Coast-$14, San Joaquin-$19, Tulare Lake-$86, South Lahontan-$150, South Coast-$252.

estimated $170 million; and benefits of the 11.6 million visitors to 10 of the 22 federal Central Valley Project (CVP) reservoirs totaled $208 million. In addition to the half-billion dollars described above, a similar amount may have been spent at the many local and regional reservoirs and streams (CADWR 1994). These estimates put the total annual value of water-related recreation statewide at $1 billion or more.

Estimates of Net Value Loss Per Acre for Large, Intense Wildfires

Large, intense wildfires can both harm and benefit consumptive uses of water. As previously stated, fire often produces a short-term increase in water yield. If this water can be captured and stored, it can be put to agricultural and urban (including residential, commercial and industrial) uses. Unfortunately, this benefit is usually associated with increased sedimentation and water quality degradation. The type of water use involved plays a major role in determining whether the outcome is positive or negative, but the overall net effect is almost always negative.

As mentioned earlier, large, intense wildfires might produce 0.1 to 0.8 acre-feet of additional runoff per acre annually for the first few years. In the best situations about half of this might be captured and stored for consumption. Depending upon location, the value of the additional water would be between zero and $1,600 an acre-foot. At $60 an acre-foot[7], this increased water yield would be worth from $3 to $12 per acre burned on an annual basis.

Most surface water consumed in California must be stored for later use. Reservoirs trap sediment, resulting in decreased capacity. Large, intense wildfires accelerate sedimentation rates, thereby reducing reservoir storage capacity and the expected life of the impoundment. Replacement capacity is very expensive to construct. For example, the proposed Los Vaqueros Reservoir Project would store 100,000 acre-feet of water at an estimated cost of $450 million (CADWR 1994) or about $4,500 per acre-foot of storage capacity. Enlargement of Shasta Reservoir could increase storage 9.7 million acre-feet at a cost of $4.5 billion or about $464 per acre-foot of storage space. An acre-foot equals about 1,613 cubic yards. Therefore, an intensely burned acre producing an extra 25 cubic yards of sediment the first year after burning would remove about 0.015 acre-feet of reservoir storage capacity. This would be a loss per acre burned of about $7 at an expanded Shasta Lake and $70 at the newly constructed Los Vaqueros Reservoir. Excavation and removal of the sediment generally costs between $4 and $40 per cubic yard, depending on factors such as end hauling distance to disposal sites (M. Bollander, Los Angeles Dept. of Public Works; C. Mitchell, El Dorado National Forest, pers. comm.). This translates to a cost that ranges from $6,452 to $64,520 per acre-foot of removed sediment, which is why it is not often adopted as a practical solution in the case of large reservoirs.

Consumptive use of water, particularly urban uses, suffer most acutely from: (1) direct fire damage to waterworks, and (2) the increased turbidity produced by large, intense wildfires. Neither is quantifiable in the abstract. Water purveyors look for the least expensive and most expeditious ways to cope with the advent or increased frequency in episodes of highly turbid raw water. There are many ways that this type of problem can be addressed. Water purveyors can, in some cases, change their water sources (e.g., drill a well or move the diversion point further upstream). They may be able to increase the storage of raw water, so they can shut

[7] *The assumed statewide average, as discussed earlier.*

off the diversion during periods of high turbidity in the supply. Likewise, they can increase the storage capacity of treated water, so they can suspend water treatment during periods of high turbidity. They can add pretreatment, like sedimentation basins or flocculation, to remove most of the suspended sediment prior to filtration. Alternately, they can install filtration systems that can handle higher turbidity levels efficiently. The costs of these solutions vary widely. Prudent operators will choose the method(s) that best meet their needs at the least cost. Such costs are so dependent on circumstances that no average or typical expenditure can be assigned.

Water conveyance structures such as penstocks and flumes are also at risk to damage from large, intense wildfires. Damage to these must be calculated on a case-by-case basis, given the variability in structure type, accessibility for repair, and degree of damage.

Flood control suffers twice from the effects of large, intense wildfires. First, as we saw in the previous discussion of chaparral lands, the frequency of large floods can be dramatically increased. For example, precipitation that would normally produce a moderate flood may suddenly be capable of producing a much larger runoff event. In a hypothetical case, a community might have to spend ten times as much for facilities capable of providing increased flood protection. Second, increased sediment and debris in flood basins costs between $4 and $40 per cubic yard to remove and dispose. Where increased sedimentation rates from intense fires are 1 to 200 tons/acre/year, annual costs can range from $0 to $8,000 per burned acre for the first few post-burn years, and this does not include the cost of potential flood damage.

Hydropower generation can be both benefited and adversely impacted by large, intense wildfires. As previously stated, fire often produces a short-term increase in water yield which can sometimes benefit hydropower production, but this benefit is often associated with increased sedimentation and water quality degradation. Assuming a water value of $70 per acre-foot[7] for hydroelectric generation, an increase of 0.5 acre-feet of water per acre intensely burned, and a utilization rate of 50 percent, the value of an acre intensely burned would be about $17.50 for the first year. This value would decline to near-zero over an 8-year period. If the increased sedimentation rate is 25 cubic yards/acre/year and the cost of removing sediment from forebays is $4 per cubic yard, the cost of the increased sedimentation would be about $100 per acre burned per year. Furthermore, there would be increased costs associated with additional wear and tear on mechanical equipment, which cannot be quantified readily. The net quantifiable effect of intense wildfire on hydropower generation is estimated to be a loss of $82.50 per acre burned per year for the first 2 to 3 years following wildfire (i.e., $17.50 per acre - $100 per acre = -$82.50 per acre).

Fisheries assets are influenced by the quality of stream habitat that can be impacted by wildfire. Potential impacts from fire include increased sedimentation,

[7] *Value given by Romm and Ewing (1987) for the Upper Feather River.*

water temperature, and nutrient loading (Kaczynski 1994). It is not possible, however, to quantify the impact a large wildfire will have on the value of commercial and sport fishing. For instance, the amount of sedimentation that occurs will depend on the soil type and slopes present. Even though it is not possible to produce a general relationship between hillslope impacts and reduced number of fish on a statewide basis, it is clear that the impacts from intense wildfire can be severe.

Wildfires reduce recreational assets in watersheds primarily through diminished aesthetic values. While it is still possible to white-water raft down a canyon that has been severely burned, most people would agree that the lowered aesthetics reduce the value of the experience. This type of phenomenon is not readily quantifiable on a dollar per acre basis. By extension, most water-related recreation losses, including reservoir recreation, produced by severe wildfire are not readily quantifiable. In specific cases where the effects of a fire were so severe that the number of visitor days for a particular use significantly dropped, the effects might be quantified. Relating that value to the number of acres burned would not produce reliable results, however, since most outdoor recreation is concentrated on a few scattered, small sites. For example, of the 12 major white-water rafting rivers in the state, more than half the use is concentrated on two relatively short reaches of one river, the American.

Watershed rehabilitation is a real and quantifiable cost of large, intense wildfires. To reduce the adverse impacts previously described, emergency watershed rehabilitation plans are implemented on severely burned watersheds with valuable downstream beneficial uses. It is common to aerial seed the most intensely burned areas with native and non-invasive species of grasses. Ordinarily, only 10 to 25 percent of the burn area is seeded in chaparral areas and less in forested areas (B. Parker, CDF, San Luis Obispo, pers. comm.). Costs range from $30 per acre to $200 per acre and average approximately $60 per acre.

Conclusion

Large intense wildfires negatively impact both water as a commodity and water as an element of the environment. The occasional, short-term positive gains from increased water yield are more than offset by the frequent short and long-term negative impacts of increased peak flows, increased sedimentation and decreased water quality (see Table 18). Dollar estimates for these impacts are elusive, notoriously unreliable, and there is great variability from one site to another in the averages presented here.

Table 18. Impacts Associated with Intense Wildfire

Beneficial Use	Benefit (+) or Cost (-) Per Acre Burned ($)	Comments
Water Yield	+$3 to +$12	1st two years
Hydropower generation	+$17.50	1st two years
Reservoir Storage Capacity	-$9 to -$90	1st two years
Reservoir Sedimentation	-$40 to -$100	1st two years
Debris Basin Cleanout	0 to -$8000	Southern CA
Watershed Rehab	-$30 to -$200	1st year only
Water Quality	negative, unquantifiable	Increased turbidity, suspended sediment
Flooding	negative, unquantifiable	Increased peak flow, debris
Fisheries	negative, unquantifiable	Increased sediment, water temperature
Recreation	negative, unquantifiable	Degraded aesthetics

Wildlife, Habitat, Plants, and Ecological Health[9]

Fire Effects on Wildlife

Fire can have two markedly different effects on wildlife habitats. Large fires do not burn evenly and as a result produce a mosaic of vegetation and post fire plant community succession. Alternatively, at a smaller scale, an intense stand-replacing fire can reduce habitat heterogeneity and foster a uniformity of food and cover value particularly in areas of similar slope, aspect, and soil type. Both outcomes may either be positive, negative, or exhibit no particular effect depending on the degree of habitat patchiness, the wildlife species of concern, and other topographic, climatic, and biological variables influencing fire effects. Similarly, the size, number, distribution, shape of unburned areas, and fire history of adjacent areas can markedly influence the population response of a particular wildlife species. Consistent generalization of the effects of post fire habitat conditions and their implications for wildlife species is not possible. Species may be favored, negatively affected, or exhibit no particular response to the post fire environment.

The general societal and frequently institutional view that fire in all its forms and potential locations results in a wholly negative effect on wildlife is mistaken. California's landscapes are dynamic expressions of climate, topography, soils, and vegetation that are continually changing at a variety of spatial and temporal scales as a result of both natural and human-caused disturbance and subsequent plant community succession. A disturbance regime characteristic of the physical environment of California was present before influence by European man and created habitats in which plants and animals had to adapt and perpetuate their kind. More recent and widespread influences by society on the structure and composition of vegetation brought about by various types of disturbance or the lack of disturbance (e.g., development, timber harvest, fire control policies, and

[9] *We are working closely with the Department of Fish and Game to further strengthen our analysis for this asset at risk. The discussion will be broadened to better incorporate plant communities, ecosystem health, and a more complete treatment of both game and nongame wildlife species.*

public attitudes toward fire) have influenced the distribution and abundance of many if not most wildlife species.

Evaluating the effects of change in fire regimes on wildlife in terms of economic gain or loss to society requires consideration of several factors. These include variation in fire attributes and location, population response of the species to the post fire environment separate from other influences, temporal response of the plant and wildlife community to the fire event, adaptation of species across taxonomic groups that occupy environments subject to repeated fire, and value society places on wildlife in either a generic or species-specific sense. Most of these variables have not been examined or remain unquantifiable.

Direct Effects. The direct effects of fire on wildlife populations vary depending on body size, mobility of the species in question, and the intensity and rate of fire spread. Most vertebrate species move away from fire although some (insectivorous birds, raptors) may be attracted, ostensibly to take advantage of available prey. Although some evidence of vertebrate mortality has been reported, the most common opinion is that these losses are negligible, particularly over the long term for those species of high reproductive potential (Lyon and others 1978). The effects of fire on invertebrate populations vary with habitats used and fire intensity. Populations of surface and soil inhabiting insects are generally significantly reduced although other species are attracted to the burned area. Reinvasion and recovery of pre burn insect populations and species diversity likely parallel recovery of the vegetation (Lyon and others 1978).

Indirect Effects. Fire sets the stage for significant and, depending on habitat type, long-term alteration of habitats. Plant succession is set back, and vegetation structure is significantly and immediately altered. Additional changes occur through the process of plant and animal community succession over time. The net positive or negative effect on habitat capability for all species potentially encountered along the successional continuum is uncertain. The immediate post fire environment presents all terrestrial and aquatic species with significant levels of habitat modification and microclimates that have both positive and negative effects. Long-lasting negative effects of a wildfire in present day fire regimes are likely limited to (1) localized stream habitats, late seral or climax forest habitats sensitive to fire effects and requiring long periods before reestablishment, (2) some seral habitats that through direct and indirect fire effects do not effectively regenerate, and (3) areas occupied specifically by species with unstable populations that are negatively affected by fire occurrence.

The number of species occupying an area may change little in response to fire in adjacent habitats. Bendell (1974) (fide Lyon and others 1978) summarized 22 studies of breeding birds and mammals in burned and adjacent unburned habitat. Overall, fire resulted in a slightly richer avifauna and stable mammalian fauna. Although some change in population density and trend of species was noted, 80 percent of bird and mammal populations remained about the same in density and population trends.

Examples

Late seral forest habitats may be increasingly fragmented or eliminated by fire of high intensity. Consequently, species exhibiting a preference or dependence on certain forest structural attributes characteristic of these plant communities may be directly and indirectly lost through habitat modification or displacement.

> Fire patterns in the Sierra mixed-conifer zone have changed radically in the twentieth century. The annual acreage burned may have declined by two orders of magnitude when compared with historic levels. This in turn has led to historically unprecedented buildups in fuels and to stand structures that are prone to crown fires. Because of these conditions, fires that escape initial suppression efforts — usually those occurring during extreme weather conditions — tend to become large, stand-replacing events. (McKelvey and Weatherspoon 1992 p.261).

> Prehistoric fire regimes have changed over time, and probably considerably for any given climate and vegetation groups, due to human influence. Modern fire control has attempted to remove fires from wildlands. Instead of removing fires, the result has been a gross distortion in the fire regimes, removing most fires of low and intermediate severity and size and increasing the proportion of large, high severity fires (Martin and Sapsis 1992 p.150).

It is axiomatic that fire suppression cannot remove fire from the landscape in perpetuity. Modern fire control, principally as a result of its own success and resultant buildup in fuels, has been required to become increasingly effective. Technological and fire management improvements have markedly influenced the effects and behavior of fire on the landscape. Other factors have also influenced vegetation development and fire regimes and include: wetter than normal weather patterns early in this century, decrease in Native American ignitions, and increase in fire prevention through public education (W. Laudenslayer, USDA Forest Service, pers. comm.).

Fire influence on plant community succession depends on the fire regime and the plant and wildlife species present. Fire occurrence in some shrub steppe habitat types (e.g., some forms of bitterbrush and sage), given present day plant community composition, negatively affects the productivity of the landscape for certain uses. The capability of shrub steppe habitat in the post fire environment of the Cascades and eastern Sierra Nevada to support a socially valued species, (mule deer), is compromised by the influence of a competing and disturbance-tolerant introduced plant species such as cheatgrass. However, in the relatively more mesic habitats of western Sierra Nevada mixed-conifer, where fire suppression has promoted plant community maturation and contributed to a reduction in deer habitat quality, fire occurrence can have a very positive effect (K. Mayer, California Department of Fish and Game,pers. comm.). Finally, unnaturally frequent patterns of fire can overwhelm the inherent ability of many fire adapted species of plants to sustain themselves. This results in type conversion to habitats adapted to a more frequent or intense fire regime (e.g., coastal sage scrub is converted to annual grassland).

California's Mediterranean plant communities, composed of many fire adapted species, depends on fire disturbance to perpetuate the type. It follows that resource use by plant and wildlife species that make up these dynamic communities would exhibit adaptations consistent with periodic habitat disturbance. These adaptations include lack of specialization in conifer habitats, enhanced dispersal capabilities, and high and variable birth rates (Udvardy 1969).

The potential negative effects of present day wildfire behavior on specific fire-sensitive species are clear. Habitat alteration that results in negative effects of any duration or the direct loss of individuals in a small population that is demographically tenuous may result in local extinction and increased risk to the species across the remainder of its range. For example, a major concern is fire risk to preferred habitat of the California spotted owl in the Sierra Nevada (USDA Forest Service 1995).

Assigning Value Lost or Gained

Several factors must be considered when determining the scope of the economic value of wildland fire's impact on wildlife. For example, Althaus and Mills (1982) suggest that:

> Resource output that cannot be readily measured in dollars should not be forced into the economic analysis. Fireeffects on rare and endangered species are examples of this class of outputs. Intended resource use plays an important role in determining fire effects. A resource loss takes place only if the resource output would have occurred in the absence of the fire

Wildlife values are generally expressed in terms of the value of a consumptive use (e.g., hunting) or non-consumptive use (viewing, bird watching, etc.). However other values also exist and include existence value (e.g., the value assigned to the knowledge that a species exists in a particular place) or bequest value (e.g., the value assigned to the knowledge that a resource will exist for the enjoyment of one's heirs). It is likely that existence and bequest values are significantly greater than the more direct forms of value assigned to wildlife (N. Dennis, Jones and Stokes Associates, pers. comm.). A major tool for determining wildlife value lost or gained for use of natural resources that are not traded in markets is contingent valuation. The contingent valuation method (CVM) is a survey technique that constructs a hypothetical market to measure individuals' "willingness to pay" or to accept compensation for different levels of non marketed natural and environmental resources. The CVM is the only method available to measure other resource values, such as the benefits the public receivesin existence and bequest values, at various levels of certainty, of unique natural environments or species (Loomis 1993).

CVM has been employed to assess the value of deer, spotted owls, gray whales, goose hunting, wildlife viewing, waterfowl in the San Joaquin Valley, salmon as a product of water quality, and several other species or area specific examples. However, the technique has not been applied to fire effects or other large scale (e.g., a statewide assessment area) habitat perturbations on wildlife (J. Loomis, Colorado State University, pers. comm.).

Determining the effects of fire on populations of all species of wildlife at a statewide scale is not feasible. Similarly, assessing the economic implications of fire on wildlife without the benefit of recognized valuation techniques makes quantitative value judgments more than problematic. Given these observations, it is only possible to make a qualitative judgment concerning the potential impact of fire on all wildlife species, in the aggregate, at a spatial scale represented by the state of California.

Fire was a common influence on the structure and function of California's ecosystems in prehistoric times with as much as 5.5 to 13 million acres burning annually on the average (Martin and Sapsis 1992). Fire regimes varied in period between fires, seasonality, dimension, and other characteristics. The fire regime exhibited under present day fire suppression policies, and as influenced by other historic variables, is one of many small low intensity fires and one of markedly more severe, less frequent, and large size fires. Nevertheless, when one considers qualitatively the economic effect of wildfires on wildlife value for all species, fire regimes, and wildland habitats at the scale of the state, it is likely that fire, at least over the short term, has had a net neutral if not beneficial effect (R. Barrett, UC Berkeley, pers. comm.; W. Laudenslayer, USDA Forest Service, pers. comm.).

Since the work presented in this section was completed, we have initiated a cooperative process with the Department of Fish and Game to refine the methods and data utilized here. An updated wildlife and ecosystem health assets report will be issued upon completion of this process.

Aggregating Values of Assets at Risk Statewide and at Ranger Units

The Fire Plan Process

As part of the fire plan, a methodology has been developed for a coarse-level aggregation of individual assets at risk into a single value measure for a given geographic area. Through this process, geographic areas will be ranked based on the potential impacts (“total cost”) of a large fire event, and the likelihood of a large fire event. The objective is to identify high-risk/high- value areas. This coarse statewide analysis will provide a better understanding of the spatial distribution of the assets protected and their risks of fire damage. The statewide analysis serves as a “pointer” to where prefire projects might be needed, and aids in the identification of the “state interest” in terms of where investment of state resources is appropriate.

The process of designing and ranking prefire projects, discussed below, will involve a more detailed and quantitative analysis of assets at risk. This process, which will involve asset stakeholders, will allow the department to rank potential projects based on costs and benefits, and quantify the appropriate state contribution to cost-sharing efforts.

Mapping and Ranking Values of Assets at Risk

The previous portions of this appendix have detailed the methods used for estimating the values of assets. In addition, since the fire plan process involves identifying high value areas based on total cost of a potential large fire event, suppression costs and rehabilitation costs must also be included in the asset analysis.

For the coarse, statewide analysis, each asset at risk is represented within the GIS using the best available statewide digital data sources. For a given asset, geographic areas will be ranked as high, medium or low based on potential impacts from a large fire event, if one were to occur. A large fire event can be thought of as a high intensity fire of at least 5,000 acres. Rankings are developed based on the potential physical fire effects as well as the human valuation of those effects. For example, for air quality the physical effects of a large fire in timberlands is higher than grasslands due to production of a larger volume of smoke. The valuation of this effect will differ based on the additional factor of how many people are affected within specific air basins. For example, a timberland fire affecting the Northeast Plateau air basin will have a lower ranking than one that affects the Sacramento Valley air basin. The specific methodologies for mapping and ranking each asset follows this general discussion.

For the purpose of ranking potential impacts for a given asset, a common statewide geographic unit is required. To link the analysis to a common map source used by department field units, the seven minute quad (1:24,000 scale) boundaries were selected as a base. Since they cover large areas (about 35,000 acres), quads are divided into ninths (about 4,000 acres). The size of these units roughly corresponds to a "large fire event" The significance of this is that it can be assumed that if an asset occurs in the unit, even as a point location (e.g., a nest site or historic building), it will be affected by a large fire event.

By ranking all assets for common geographic units, the results can be displayed in a matrix similar to Table 19. Table entries, potential impact of a large fire event, are either 0 (asset not present), 1 (Low), 2 (Medium), or 3 (High).

Table 19. Example Asset at Risk Ranking Matrix

Quad	9th	Popu-la-tion	Flood	Fire Sfty	Air Qlty	H2O Qlty	Non-Game Wild-life	Ecol Hlth	Game	Rec-rea-tion	H2O Stor-age	Hydro Power	Hist-oric Bldgs	Scenic Areas	Range	Timber	Struc-tures	Suppr-ession Costs	Rehab Costs
Colfax	1	3	0	2	2	1	1	1	1	1	2	3	0	1	1	0	3	2	1
	2	3	0	2	2	1	2	2	1	1	3	3	0	1	1	0	3	2	1
	3	2	0	2	2	1	2	2	1	1	2	3	0	1	2	0	2	1	1
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	9	1	0	1	2	1	2	1	1	2	3	3	0	1	2	0	1	1	1
Westville	1	1	0	1	1	1	1	1	1	1	2	0	0	2	2	0	1	1	1
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

Identification of High-Value Areas

The asset rankings in the above matrix must be combined into an overall ranking based on the entire spectrum of assets the department protects. The result of this process is a designation of high-value areas. By including all impacts of a large fire event, both economic and non-economic, high-value areas represent places where the total cost plus damage of a large fire event would be greatest.

Given the ranking approach used, a scheme for weighting assets at risk, or assigning relative values, must be developed in order to aggregate values across asset categories. Obviously, assigning weights that explicitly quantify the relative importance of the various assets to the state interest will be controversial. However, it cannot be avoided if high-value areas are to be identified. It is not the role of the department to attempt to single-handedly determine these weightings. Rather, this task will be done through the stakeholder process at the ranger unit level.

The State Constitution provides “direction” in terms of the priority ranking various public issues: (1) public safety; (2) public health; (3) the environment; and (4) public welfare. Using these categories as an organizing framework, Table 19 suggests how assets might be grouped.

While the Constitution suggests a higher priority of weighting as you move from left to right in Table 19, it provides no specific weights. While the magnitude of impacts is potentially more severe on the left, the frequency with which impacts occur is far greater on the right. For example, while a large fire event that takes human life is tragic, it is less frequent than the event that has major impacts on public welfare.

Map Production and Distribution

For each asset at risk, two maps will be produced. First, the ranking map displays quad ninths shaded as white (asset not present), light gray (Low), gray (Medium), or black (High). Second, the asset map shows the actual data used to generate the rankings, for example recreation areas, watersheds prone to fire-flood, historic buildings, or range vegetation types. Both of the maps are produced in black and white in 8.5" by 11" format. This will allow stakeholders with standard printers to access the files electronically. It also will allow the department to easily reproduce the maps for distribution.

Field Validation of Assets at Risk

The initial coarse asset analysis for the state will be “fine-tuned” by successive ranger units. For each asset, GIS data will be provided to the ranger unit for the actual location of the assets. The data included may be finer-scale (e.g., from county GIS programs) than that used for the statewide analysis. A ranking matrix (Table 20) generated from the asset data will be provided to ranger units as the database file associated with a GIS data set of quad ninths.

Table 20. Assignment of Assets at Risk to Public Issue Categories

Public Safety	Public Health	The Environment	Public Welfare
Population	Air quality	Non-game wildlife (2) (3)	Game wildlife (3)
Fire-flood watersheds	Water supply	Ecosystem health (3)	Recreation
Firefighter safety (1)			Water storage
			Hydroelectric power
			Historic buildings
			Scenic areas
			Range
			Timber
			Structures
			Fire suppression costs (1)
			Rehabilitation costs(1)

(1) Methodology for mapping and ranking not yet developed.
(2) Includes numerous assets at risk for different rare species, plant communities, and habitats.
(3) Methodology for mapping and ranking under development in cooperation with Department of Fish and Game.

Field validation involves three possible refinements of the statewide analysis. First, the scale of the asset data, changes since mapping occurred, or mapping errors could lead to improper ranking of some quad ninths. For example, a new subdivision may not appear in the population asset data, leading to the associated quad ninth being erroneously ranked aslow.

Second, the ranking procedure used at the state level foran asset at risk may be inadequate to capture all instances of high value. For example, the ranking procedure for air quality is based on fuel type and population within air basins. At the local level, even though the larger air basin is sparsely populated there could be a small inversion-prone valley containing settlement especially sensitive to smoke, for example a retirement community. This could merit a higher ranking, even though other areas in the air basin are ranked low.

Finally, there may be assets that have local importance that were not included in the statewide analysis. For example, a timber mill that is an important component of a local economy would not appear in the statewide framework. As a general guide to identifying assets at risk, important qualities to consider include, but are not limited to, uniqueness, economic value, public investment, and any special legal status.

There could be three processes for field validation, depending on the asset at risk (Table 21). Complete validation is used for assets that typically occur as a relatively small number of point or area locations. Actual location and fire susceptibility of all occurrences of these assets can be verified and re-mapped if necessary. For example, all state designated historic landmarks that are buildings (as opposed to plaques) can be visited, evaluated for fire susceptibility, mapped within the GIS, and ranked in the quad ninth matrix. Stream channels that feed hydroelectric power plants can probably be verified without site visits based on field knowledge of local power plants.

Table 21. Assets at Risk for Three Different Validation Procedure Classes

Complete Validation	Spot Validation	Cooperative Validation
Water quality	Population, structures	Wildlife assets at risk
Recreation	Fire-flood watersheds	Ecosystem health
Water storage	Air quality	Range
Hydroelectric power	Timber	
Historic buildings	Suppression, rehab costs	
Scenic areas		

Spot validation will be used for assets that typically cover the entire ranger unit in complex spatial arrangements, where complete validation is not feasible. The ranking map can be scanned for obvious omissions, inconsistencies, or gross errors. For these problem areas, better information will be needed through field experience or actual site visits. The procedure will be to change the quad ninth ranking in the matrix and document the reason for the change. For most of these assets, it will not be feasible to change the actual base data since it will typically involve a significant mapping effort. For example, mapping the actual boundaries of timber stands is probably not an efficient use of departmental resources (and could meet landowner resistance).

For assets that require a specific expertise, it may not be possible for the department to independently validate the data, thus requiring a cooperative validation process. For these assets, the department will need to engage local expertise, such as Fish and Game biologists or extension agents. Further, the stakeholder process at the ranger unit level will help to validate the assets analysis, as well.

Since this is the department's first attempt at the considerable task of ranking and validating all assets susceptible to fire, it is impossible to initially design a framework that captures all important asset values. The asset framework and validation process will be refined as the fire plan process progresses through the ranger units based on direction from the Board of Forestry, department field staff, and stakeholders.

Prefire Management Project Selection and Cost Sharing

Following the aggregation of assets at risk, as described above, and the overlaying of the high fire hazard data layer, the ranger units will be able to identify the high risk/high value areas that are most in need of prefire management projects. Once these areas are identified, the department can begin to design potential prefire projects (such as fuels management, forest health, land use planning, and fire prevention) to reduce suppression costs and impacts to assets at risk. The next step in the fire plan process is to determine how limited funds should be allocated among these potential projects. Given that department funds for prefire projects are limited, the department must carefully and systematically select the projects that provide the greatest benefit for a given investment.

The primary goal of the department in implementing prefire projects is the reduction of fire suppression costs and subsequent disaster relief to the state; reduction of losses to assets is of secondary importance. Thus, in selecting among prefire projects to be applied in high risk/high value areas, the department will look first at a project's potential to reduce state suppression and disaster relief costs should an ignition occur during a severe fire weather period. Those projects that provide the greatest potential suppression cost savings for a given project cost will be highest on the department's list for implementation.

Another key factor that must be identified is who is receiving the benefits of the prefire projects and who, accordingly, should be responsible for paying for them (i.e., private landowners, local, state, or federal government, or interest groups). Thus, another step in the project selection and funding process is to determine these factors and to approach the benefiting parties to request that they share in project funding. The department will not be able to implement projects for which other benefiting parties do not provide an adequate amount of cost-share funding, particularly where these projects do not offer a significant potential reduction in fire suppression costs. The process of working out cost-sharing of prefire projects will be carried out through the stakeholder processes conducted at the ranger unit level.

For each potential prefire project considered by a ranger unit, a framework such as that presented in Table 22 will need to be completed. The table shows, for a hypothetical prefire project, which stakeholders — state, local, federal, or private — would benefit. Beyond this simple identification of values and beneficiaries, determinations could be made, to the degree possible, of the relative extent of benefit and, thus, the relative shares of the project costs that each stakeholder should be considered to be responsible to support. For example, assuming that each cell with an X in Table 22 represents an equal benefit value, then the state would be expected to support 1/2 of project cost (split among the Air Resource Board, Department of Water Resources, Department of Fish and Game, and the Department of Forestry and Fire Protection), local government would be expected to support 3/8ths, and private parties 1/8th of project costs.

Table 22. Identifying Assets Affected and Stakeholders for a Hypothetical Prefire Project

	Stakeholders			
Assets at Risk	State	Local	Federal	Private
Air Quality	X (ARB)	X		
Range				
Recreation				
Structures		X		X
Timber				
Watersheds	X (DWR/DFG)	X		
Wildlife and Plants	X (DFG)			
Other Assets				
Suppression and Rehabilitation Costs	X (CDF)			

Summary

The fire plan assets at risk assessment results in the identification of prefire management projects, within ranger units and across the state, that offer the greatest net benefits to the state, local government, federal government, and the private sector. The first step of this process, the statewide identification, quantification, and valuation of assets at risk to large, damaging fires, has been largely completed, although work is ongoing with the Department of Fish and Game, the State Water Resources Control Board staff, and other stakeholders to refine our approaches to wildlife, plants, ecosystem health, water, and watersheds. The second step of aggregating assets across the state on a geographically is under way. Work to refine the statewide data has commenced with the first pilot ranger unit. Once this is completed, and the fire hazard overlay added to the analysis, the ranger unit will be able to identify those areas that have the highest fire hazard and risk, and thus merit consideration for the application of prefire projects. Once potential prefire projects are identified, the beneficiary identification and cost-sharing analysis procedures can be initiated. Finally, project selection and implementation decisions can be made on the basis of which projects provide the highest benefits and have received an adequate level of funding from the various benefiting parties.

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